Nature Conservation 22: 17–50 (2017)
doi: 10.3897/natureconservation.22.20074
http://natureconservation.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
Nature Conservation
Launched to accelerate biodiversity conservation

Systematic Raptor Monitoring as conservation tool: 12 year results in the light of landscape changes in Dadia-Lefkimi-Soufli National Park

Konstantinos Poirazidis[1,2]

1 *WWF Greece, 21 Lempesi Street, 117 43, Athens, Greece* **2** *Department of Environmental Technology, Technological Educational Institute of Ionian Islands, Minotou Gianopoulou, Panagoula, 29 100, Zakynthos, Greece*

Corresponding author: *Konstantinos Poirazidis* (ecopoira@yahoo.gr)

Academic editor: *R. Julliard* | Received 7 August 2017 | Accepted 18 September 2017 | Published 3 October 2017

http://zoobank.org/AE92CC17-50E9-4C13-AE4C-D90C95A809F0

Citation: Poirazidis K (2017) Systematic Raptor Monitoring as conservation tool: 12 year results in the light of landscape changes in Dadia-Lefkimi-Soufli National Park. Nature Conservation 22: 17–50. https://doi.org/10.3897/natureconservation.22.20074

Abstract

Dadia-Lefkimi-Soufli National Park forms part of the Natura 2000 network in a region of Greece and represents one of the most diverse landscapes for raptors (birds of prey) breeding in Europe. It is adjacent to Bulgaria and Turkey and is a renowned biodiversity hotspot. WWF Greece established a Systematic Raptor Monitoring scheme in this area in 2001.This study summarises the results of the first 12 years of monitoring in the National Park. Overall, 25 to 27 raptor species were recorded by pooling data, of which20 species reproduced in the National Park. Raptors with continuous presence in the National Park exhibited stable, species-specific inter-annual variation. An average of 348±15.4 raptor territories were distributed throughout the National Park for all species. The Common buzzard (*Buteo buteo*) and the Short-toed eagle (*Circaetus gallicus*) were the most common species year-round, followed by the Lesser-spotted eagle (*Clanga pomarina*) and Booted eagle (*Aquila pennata*). The Long-legged buzzard (*Buteo rufinus*), Honey buzzard (*Pernis apivorus*) and Egyptian vulture (*Neophron percnopterus*) exhibited a noticeable drop in population numbers over the study period. A significant new entry was the re-appearance of the White-tailed eagle (*Haliaeetus albicilla),* which was recorded breeding again in the region after a 21-year absence. Species trends, along with their ecological traits, are discussed with respect to landscape changes in Dadia NP and minimum viable population and territory thresholds are proposed to outline essential conservation issues. Although a multi-year balance of the total number of occupied territories for all species was recorded, the number of common species increased compared to specialist species which had smaller, de-

Copyright *Konstantinos Poirazidis*. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

clining populations. The abandoning of traditional livestock farming, which induces an increase in closed-canopy forest coverage, might have led to the decline of the Lesser-spotted eagle, Long-legged buzzard and Honey buzzard numbers. Additional pressure is added from specialist forest dwelling raptors which are favoured by this change in habitat. The results of this study are expected to provide useful insights to facilitate conservation and management decisions about raptors and their habitat in this region.

Keywords
birds of prey, population trends, modelling, GAM, Greece, conservation

Introduction

Although Dadia-Lefkimi-Soufli National Park (Dadia NP) was established in 2003, it has had protected reserve status since 1980 as a result of its high ornithological value (Adamakopoulos et al. 1995, Kati et al. 2004a, 2004b, Catsadorakis and Källander 2010). It is a specially protected area (SPA) within the Natura 2000 network of the European Union (EU) as it supports a highly diverse raptor assemblage, hosting breeding pairs of both rare and endangered species. Examples include the last breeding colony of the Cinereous vulture (*Aegypius monachus*) in the Balkans, in addition to colonies of the Lesser-spotted eagle, the Short-toed eagle and the Booted eagle (Poirazidis et al. 2004, Skartsi et al.2008, Vasilakis et al. 2008). Out of all known European raptor species, 90% have been observed in Dadia NP (Hallmann 1979), highlighting the importance of this region for Greece and Europe. This region is also a renowned biodiversity hotspot for other taxa (Kati et al. 2004a, 2004b, Kati and Sekercioglu 2006, Kati et al. 2007, Zografou et al. 2015).

Although the landscape of Dadia NP remains heterogeneous and diverse (Schindler et al. 2008), it has changed significantly after 1970, due to both reforestation and land abandonment (Triantakonstantis et al. 2006). This land-use change affected the availability of suitable habitats for many species of raptors, as well as other taxa (Poirazidis et al. 2007, Poirazidis et al. 2010). Therefore, a Systematic Raptor Monitoring (SRM) scheme was established in Dadia NP to evaluate and improve conservation measures at regular intervals and to establish precise management actions (Witmer 2005). Many countries, at least within the EU, have established long-term raptor monitoring schemes as conservation tools (Kovacs et al. 2008). In contrast, in Greece and specifically within Dadia NP, an SRM scheme has only been established since 2001 by WWF Greece. This scheme aimed at exploring population trends by monitoring variations in the number of raptor territories. This scheme is unique as it is the only region in the whole of Greece where the whole raptor bio-community is monitored rather than just for specific species.

Therefore, the current study aimed to: (i) assess the six monitoring surveys (March to August 2001–2005 and in 2012) completed in Dadia NP since 2001 by exploring the relative variation in the number of raptor territories in this region and (ii) model population trends of raptors from 2001 to 2012, to identify key conservation issues

and explore which species are in need of immediate action. These results were expected to show the importance of SRM as a conservation strategy in the study region and as a protocol for evaluating variations in raptor numbers from which to develop focused processes to assess the drivers of these variations.

Methods

Study area

Dadia NP is located in the Evros Prefecture of Greece (N40°59" to 41°15"N, E26°19" to E26°36'), forming part of the south-eastern Rhodope mountains, bordering with Turkey in the east. The area includes two strictly protected core areas, encompassing a total of 7290ha. The altitude of the area ranges between 10m and 654m. Including the surrounding buffer zone, the area encompasses 35170ha (Catsadorakis and Källander 2010). The landscape is characterised by small and large valleys crossed by a hydrological network of both small and large watercourses. Dadia NP is dominated by forests of pines mixed with broadleaf forests. Maquis scrublands are also present in the vegetation mosaic. The most common tree species is the Calabrian pine (*Pinus halepensis subsp. Brutia*), while the Corsican pine (*Pinus nigra*) forms smaller forest patches, usually adjacent to riparian habitats. Four species of oak (*Quercus* spp.) are also present in the ecosystem. Riparian vegetation is mainly composed of Common alder (*Alnus glutinosa*) and, to a lesser extent, species like Willow (*Salix* sp.), the Black poplar (*Populus nigra*) and Tamarisk (*Tamarix spp.*) (Adamakopoulos et al. 1995, Poirazidis et al. 2004). Grazing lands, fields and villages disrupt the continuity of these forested areas, creating a characteristic habitat-mosaic that favours high landscape and biological diversity in the Dadia NP (Schindler et al. 2008).

Field methodology

In general, three main sampling methods are used for the census of breeding raptors: (i) line transects for surveying small areas on either side of a road; (ii)point count surveys in specified areas around fixed points and (iii)territory mapping (Fuller and Mosher 1987). In this study, all three methods were combined through (i) the surveillance of fixed areas from permanent vantage points, from which observations were mapped and (ii) surveillance from a vehicle along predetermined transects in which raptor activity was documented along both sides of the roads with hand-held GPS units (Schindler et al. 2011). Binoculars and telescopes were used according to standard methodology (Bibby et al. 2000, Vorisek et al. 2008, Gilbert et al. 2011). Following, Millsap and Le Franc (1988), permanent (rather than random) vantage points were selected. Twenty-four vantage points and 10road transects (see Supplementary File 1: Map of Dadia NP vantage points and line transects) were selected throughout the entire study area to

monitor the raptor population in detail and to secure the viable, long-term reproducibility of the methodology for future monitoring efforts.

Due to the topography of the area, good vantage points were limited and definitive vantage points were selected using the following criteria: (i) the point ensured the best and widest view of all neighbouring hillsides; (ii) the total area surveyed from vantage points included all main habitat types in proportion to their availability; (iii) the points were distributed equally over the entire study area, without habitat-bias towards plots with already known high raptor presence; (iv) access time to vantage points from the nearest road was short and (v) Black vulture colonies were avoided to reduce disturbance. Road transects were selected based on the following criteria: (i) how they complemented vantage points and, especially, for coverage of valley areas, where the positioning of adequate vantage points was not possible and (ii) to obtain the maximum coverage of the reserve by the two methods. Each survey was completed by two observers who alternated at sampling sites to reduce observer bias.

Details of the SRM scheme, describing both spatial and temporal parameters, are provided in Poirazidis et al. (2011). For a detailed map of the study area, transect and vantage points' position, as well as landscape and vegetation analysis, National Park limits and core areas' extension, see Schindler et al. (2008, 2015) and Poirazidis et al. (2009).

Data analysis methods

The total number of raptor species, along with the total number of individuals of each species, was recorded each year, along with details on the vantage point, transect and monitoring season. The total number of observations for each species was also recorded in a similar manner. To standardise differences in raptor numbers between years, the percentage of all recorded observations for each raptor species was calculated in relation to the total raptor observations in each monitoring year.

The number of territories was estimated using three standard steps to allow meaningful comparison. In Step 1, the observation data were entered in seven different ArcGIS layers: general flights, territorial observations, landings, synchronous observations, nest areas, meeting points and meeting point flights. The number of individuals, species, age, sex and different raptor activities were also recorded in an Access database that was interconnected with the GIS layers of Dadia NP. In Step 2, each territory was estimated independently for each vantage point and each road transect (representing 34 discrete sampling plots). When territories extended beyond the boundaries of discrete plots (continuing on to neighbouring plots), further analysis reshaped the polygon limits, creating new ones in a progressive process in which the recordings of each subsequent month in the same year were used to correct previous estimations (for details, see Poirazidis et al. 2009; Schindler et al. 2011). In Step 3, in order to define the final limits of a breeding pair's exploited territory, the total observations for each year were used for the whole breeding season. Therefore, "territory centres" (which were derived from the polygons) should not be used in a deterministic context, but in a

relative spatial context. To avoid potential bias in counting the same individual in more than one territory (and not confusing one large territory with smaller neighbouring ones), simultaneous observations from observers in different locations over the whole region were used as the tool for separation. At the time of evaluation, major raptor activities were included, such as displays and landings.

Breeding territories were classified as: "confirmed" or "possible." The classification "possible" was used when it was not possible to confirm with absolute certainty that the observations were obtained from separate individuals that maintained a separate territory. At the end, the final number of territories for each species was calculated by adding 50% of possible territories to the confirmed values (Palma et al. 2004).

Inter-annual variation in the relative number of raptor territories was explored by using the first SRM year as the starting point, appointing it with a value of 1. Then, for all subsequent monitoring years, a number was produced showing the relative difference in the number of territories per species in relation to the baseline value of 1 (Siriwardena et al. 1998).

To explore the population trends of raptors, two approaches were implemented. First, the non-parametric and distribution-free test of Mann-Kendall (MK) was applied to the annual SRM values for the number of raptor territories to statistically determine whether there was a monotonic upward or downward trend of the variable of interest over time (Baldwin et al. 2012). A monotonic upward/downward trend means that the variable consistently increases/decreases through time. The MK test is used in place of a parametric linear regression analysis, as the residuals from the fitted regression line do not need to be normally distributed. MK "tau" and "p" values were calculated, along with the Sen Slope value which is the median slope joining all pairs of observations and is expressed both by quantity per unit time and percent of the mean quantity per unit time. MK tests were applied with R programming language (R Core Team 2017) and the Kendall package (McLeod 2015). Second, the annual values of the number of territories per species from the SRM scheme were tested progressively against time with Generalised Linear Models (GLMs) with Poisson and Negative Binomial distributions and then with Generalised Additive Models (GAMs), with and without smoothing terms, in terms of cubic and cyclic cubic regression splines. GAMs were the best fitting models for these data, based on the criterion of AIC and BIC (Guisan et al. 2002).

GAMs are actually flexible extensions of GLMs. In GAMs, the linear equation predictors that are associated with the GLMs are replaced by a more general additive predictor which allows the change in abundance over time to follow any smooth curve and not just a linear form (Fewster et al. 2000). In order to capture the non-linear form of data over time, GAMs use a variety of smoothing techniques which were originally developed for smoothing scatterplots. Such smoothers are the kernel smoothers, weighted regression smoothers and running-median smoothers (Fewster et al. 2000). In the present study, smoothing splines were used which satisfy a penalised least squares criterion. The penalty criterion is applied by using cubic and cyclic cubic polynomials, the roughness of which is actually penalised by the number of degrees of freedom.

Specifically, as the degrees of freedom in a model increase, the smoothing functions increase the model's flexibility, with more turning points and gradients appearing. In GAMs, predictor variables are specified as non-parametric smooth functions (Hastie and Tibshirani 1986). GAMs were applied with R programming language (R Core Team 2017) and more specific with the R package mgcv (Wood 2012).

GAMs are also used to separate actual underlying trends from short-term fluctuations. However, the precise point where a signal is interpreted as an irregular fluctuation, rather than a long-term trend, is poorly defined; thus, for each point, a framework to delineate noise from trends must be generated (Fewster et al. 2000).

A number of diversity indices was also calculated for the raptor community in Dadia NP, following Magurran (2004). Shannon, Simpson and Invert-Simpson diversity indices were calculated, these being three of the most commonly used diversity metrics in bio-community analysis (Magurran 2004).

The Osprey (*Pandion haliaetus*), Hen harrier (*Circus cyaneus*) and Red kite (*Milvus milvus*) were observed in Dadia NP, but were excluded from the analyses because they are currently, at least, non-breeders in the area. Similarly, the Black kite (*Milvus migrans*) was excluded from population trend analyses as it occupied territories close to Dadia NP, but did not breed inside the NP. The Western marsh harrier (*Circus aeruginosus*) was also excluded from the analysis, as it was absent during the first year, only establishing territories in the final year of monitoring. The colonial vulture species Griffon vulture (*Gyps fulvus*) and Cinereous vulture (*Aegypius monachus*) were also observed, but excluded from all analyses, as they form colonies and undertake common and long distance flights for foraging and do not present a strict territorial behaviour similar to other raptors. Finally, species that were sporadically recorded across years (Imperial eagle (*Aquila heliaca*), Lanner falcon (*Falco biarmicus*) and White-tailed Eagle were not included in this analysis.

Results

Presence and relative abundance

Dadia NP was monitored from March to August 2001–2005 and in 2012 (i.e. totalling six censuses) within the framework of the SRM. A total of 23 raptors that form territories were recorded over all breeding seasons (Table 1).

The number of Egyptian vulture territories was counted and evaluated in the SRM. Due to the rapid population decline of this species in the study region (and also in SE Europe), specific additional monitoring schemes were implemented from 2009 to 2017 in Dadia NP. The aim was to secure the Egyptian vulture survival in Greece and Bulgaria. More details are included in the official project's website The Return of Neophron (http://www.lifeneophron.eu/en/index.html).

One-way ANOVA tests indicated that in a species-specific context, the presence of raptors was stable between monitoring years (25.17 ± 1.47, $F_{(4.1)}=2.172$, $p=0.465$).

Table 1. Relative frequency of raptors recorded during each Systematic Raptor Monitoring year in Dadia-Lefkimi-Soufli National Park. Percentages are calculated from the total of individuals observed from March to August 2001–2005 and in 2012. Data are shown in a decreasing value-order with respect to the first year of observation.

Species of raptors	1st SRM year (2001)	2nd SRM year (2002)	3rd SRM year (2003)	4th SRM year (2004)	5th SRM year (2005)	6th SRM year (2012)
Buteo buteo	40.07	27.64	26.55	27.11	29.39	27.58
Circaetus gallicus	20.61	25.07	26.19	24.07	22.90	21.47
Clanga pomarina	4.49	5.79	4.18	5.75	4.81	5.13
Neophron perncopterus	4.23	4.88	3.87	5.87	5.01	1.89
Aquila pennata	3.97	3.49	3.78	3.19	2.99	4.65
Pernis apivorus	3.25	3.49	2.63	1.17	2.11	2.46
Accipiter nisus	2.73	3.03	2.41	1.21	1.52	2.74
Falco tinnunculus	1.83	1.55	0.91	2.04	1.40	1.09
Accipiter gentilis	1.80	2.29	1.08	0.91	1.60	1.96
Aquila chrysaetos	1.53	1.39	1.06	1.72	1.84	0.96
Buteo rufinus	1.01	0.61	0.53	0.64	0.72	0.28
Falco subbuteo	0.60	0.63	0.27	0.34	0.30	1.30
Aquila heliaca	0.37		0.11	0.09	0.01	
Falco biarmicus	0.37		0.00			
Milvus migrans	0.49	0.83	0.22	0.77	0.81	1.09
Falco peregrinus	0.26	0.04	0.18	0.58	0.41	0.28
Accipiter brevipes	0.26	0.26	0.13	0.04	0.21	0.24
Circus aeroginosus		0.04	0.09	0.03	0.17	0.72
Circus cyaneus					0.01	0.04
Circus pygargus				0.01	0.01	0.09
Haliaeetus albicilla			0.04		0.21	0.74
Milvus milvus						0.02
Falco vespertinus		0.09				

This pattern was similar in the whole NP and at vantage point plots (24.83±1.47, $F_{(2.3)}$=0.316, p=0.750) and along road-transect plots (20.67±1.37, $F_{(3.2)}$=0.549, p=0.697).

The most common species were the Common buzzard, Short-toed eagle and Lesser-spotted eagle, with an average relative abundance of 29.72%, 23.38% and 5.02% of all raptor species per monitoring year. All other species had a relative abundance of less than 3% per monitoring year (Table 1).

The relative abundance of the Egyptian vulture was 4.8% (range: 3.87–5.87%) in 2001–2005, but dropped to 1.89% in 2012, indicating a rapid decline in the number of breeding territories over the course of a decade. In addition, the presence of the Long-legged buzzard decreased by 70% from 2001 to 2012 (Table 1). The Lanner falcon was only recorded in 2001. The relative abundance of the Imperial eagle declined over the observation period, with this species being absent in both 2005 and 2012 (Table 1).

Relative variation in territory number and diversity

The Booted eagle and Golden eagle (*Aquila chrysaetos*) displayed negative values in 2004 (SRM year 4); however, the population had re-established by 2012 (SRM year 6) to similar levels as in 2001 (SRM year 1) (Figure 1). A positive relative increase of 4.9% was documented for the Booted eagle. In comparison, the Golden eagle had a similar number of territories in 2012 (SRM year 6) as in 2001 (SRM year 1). The number of Lesser-spotted eagle territories increased from 2001 to 2004 (SRM year 1–4); however, the number of territories in 2012 (SRM year 6) was similar to that in 2001 (SRM year 1) (Figure 1). The only eagle for which the number of territories increased from 2001 to 2005 and was maintained in 2012 was the Short-toed eagle, with a 22% relative increase (Figure 1).

Buzzards presented two opposing trends in the relative number of territories. The Common buzzard occupied more territories across all survey years, with a relative increase of 11.5% (Table 2). In comparison, the relative number of territories of the Long-legged buzzard and the Honey buzzard strongly declined by 57% and 45%, respectively (Figure 2). Falcons also exhibited contrasting trends. For instance, after a continuous increase from 2002 to 2005, the number of Eurasian kestrel (*Falco tinnunculus*) territories noticeably declined, reaching a negative value of 29% with respect to the baseline value (Figure 3). In comparison, the number of Peregrine falcon (*Falco peregrinus*) and Hobby (*Falco subbuteo*) territories strongly increased by 75%

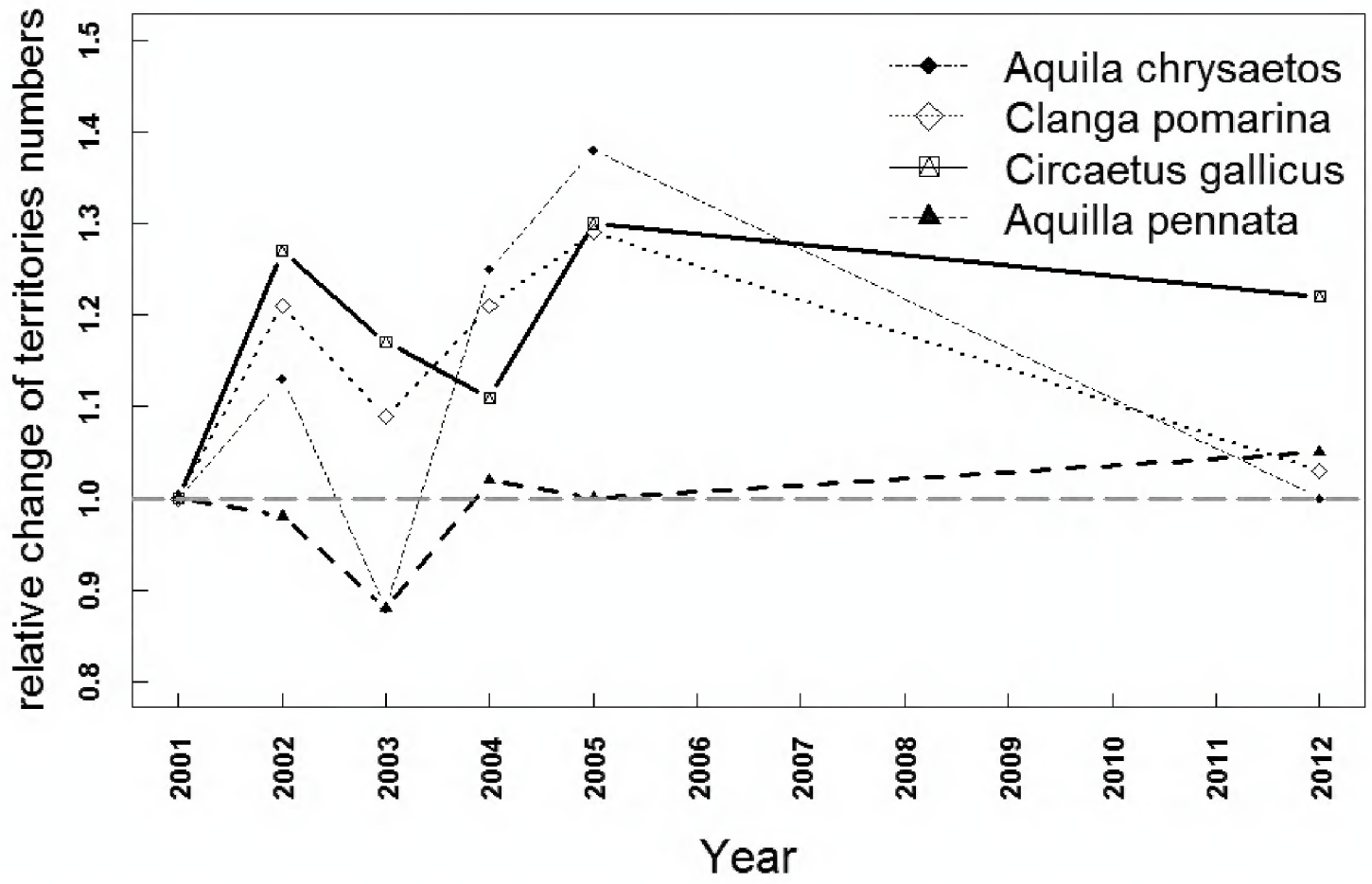


Figure 1. Relative variation in the territory numbers of eagles in Dadia-Lefkimi-Soufli National Park during the Systematic Raptor Monitoring surveys (March to August 2001–2005 and in 2012).

Table 2. Relative variation in the number of raptor territories in the Dadia-Lefkimi-Soufli National Park during the Systematic Raptor Monitoring surveys from March to August 2001–2005 and in 2012. Calculations were made in relation to a "baseline value," with the number of territories in year 1 being assigned the value of 1. Data are shown in decreasing value-order with respect to total variation (%).

Species of raptors	**1st SRM year** (2001) *"baseline value"*	**2nd SRM year** (2002)	**3rd SRM year** (2003)	**4th SRM year** (2004)	**5th SRM year** (2005)	**6th SRM year** (2012)	**Total Variation (%)**
Falco peregrinus	1	0.25	1.50	1.50	1.50	1.75	**75.0**
Falco subbuteo	1	1.38	0.54	1.31	1.08	1.46	**46.2**
Accipiter brevipes	1	2.40	1.60	0.40	1.20	1.40	**40.0**
Accipiter gentilis	1	0.97	0.87	1.03	1.26	1.24	**23.7**
Circaetus gallicus	1	1.27	1.17	1.11	1.30	1.22	**22.2**
Buteo buteo	1	1.17	1.14	1.02	1.11	1.11	**11.4**
Aquila pennata	1	0.98	0.88	1.02	1.00	1.05	**4.9**
Clanga pomarina	1	1.21	1.09	1.21	1.29	1.03	**2.9**
Aquila chrysaetos	1	1.13	0.88	1.25	1.38	1.00	**0.0**
Accipiter nisus	1	0.81	0.86	0.76	0.90	0.78	**-22.2**
Falco tinnunculus	1	0.90	1.00	1.26	1.45	0.71	**-29.0**
Pernis apivorus	1	0.95	0.81	0.65	0.86	0.54	**-45.6**
Neophron percnopterus	1	1.05	0.86	1.09	0.86	0.45	**-54.5**
Buteo rufinus	1	0.86	0.86	0.86	1.14	0.43	**-57.1**
Circus aeruginosus	0.00	1.00	1.00	0.00	2.00	6.00	**500.0**
Total territory variation	1	1.07	1.04	1.01	1.12	1.02	**2.1**

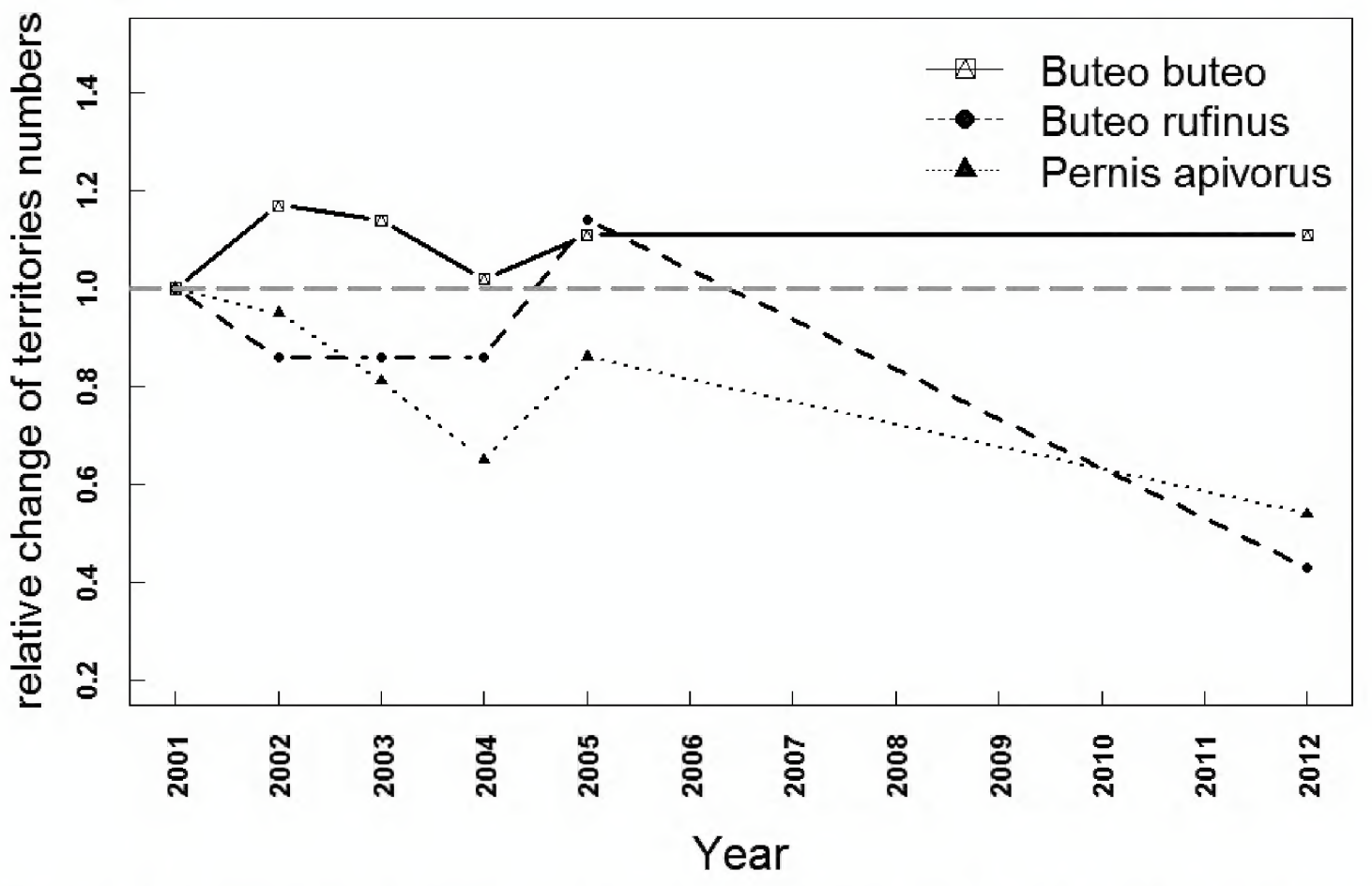


Figure 2. Relative variation in the number of territories of buzzards in Dadia-Lefkimi-Soufli National Park during the six Systematic Raptor Monitoring surveys (March to August 2001–2005 and in 2012).

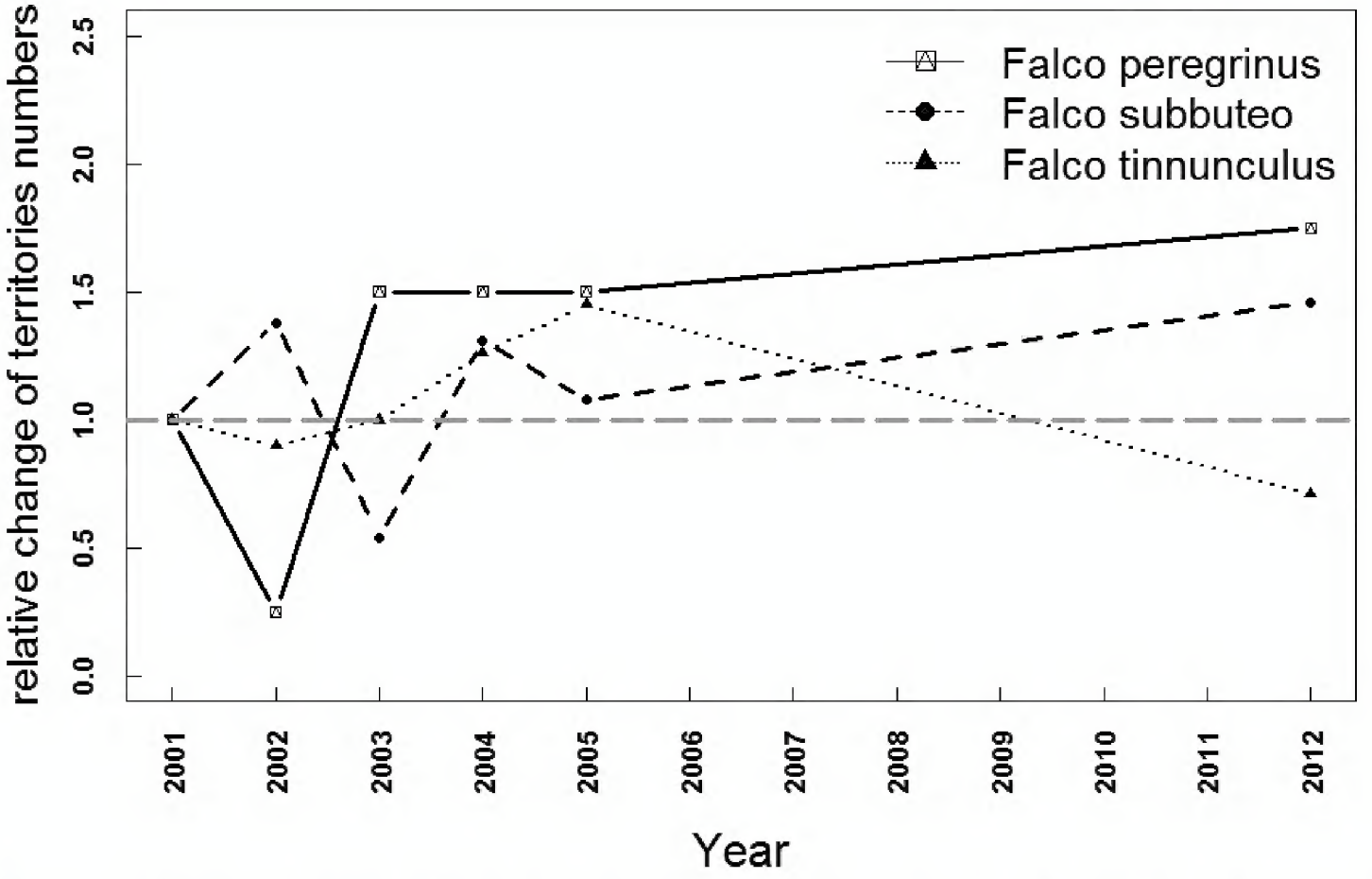


Figure 3. Relative variation in the number of territories of falcons in Dadia-Lefkimi-Soufli National Park during the six Systematic Raptor Monitoring surveys (March to August 2001–2005 and in 2012).

and 46.2%, respectively (Table 2), with this trend being noticeable in comparison to all other raptors.

With respect to hawks, the number of Sparrowhawk (*Accipiter nisus*) territories decreased from 2001 (SRM year 1) to 2012 (SRM year 6) (Figure 4). The number of Levant sparrowhawk (*Accipiter brevipes*) and Northern goshawk (*Accipiter gentilis*) territories increased by the year 2012 (SRM year 6); however, the Levant sparrowhawk exhibited major fluctuations in territory number across the years (Figure 4). The Egyptian vulture exhibited the largest relative decrease in territory number of all species, reaching a negative value of 54.5% in 2012 (Table 2, Figure 5), holding just five active territories.

The diversity of the raptor assemblage in Dadia NP decreased in the region over the study period based on all three indices (Shannon, Simpson and Invert-Simpson) (Figure 6). However, all indices presented generally high values of diversity overall (Simpson: 0.834±1.01, Shannon: 2.194±0.04, Invert-Simpson: 6.048±0.39).

Overall percentage change between the first and last year of the SRM

Three species exhibited noticeable overall increases in their presence in Dadia NP from 2001 to 2012; namely, the Common buzzard, the Short-toed eagle and the Northern goshawk. In contrast, four species exhibited noticeable decreases; namely, the Common kestrel, the Egyptian vulture, the Eurasian sparrowhawk and the Honey buzzard.

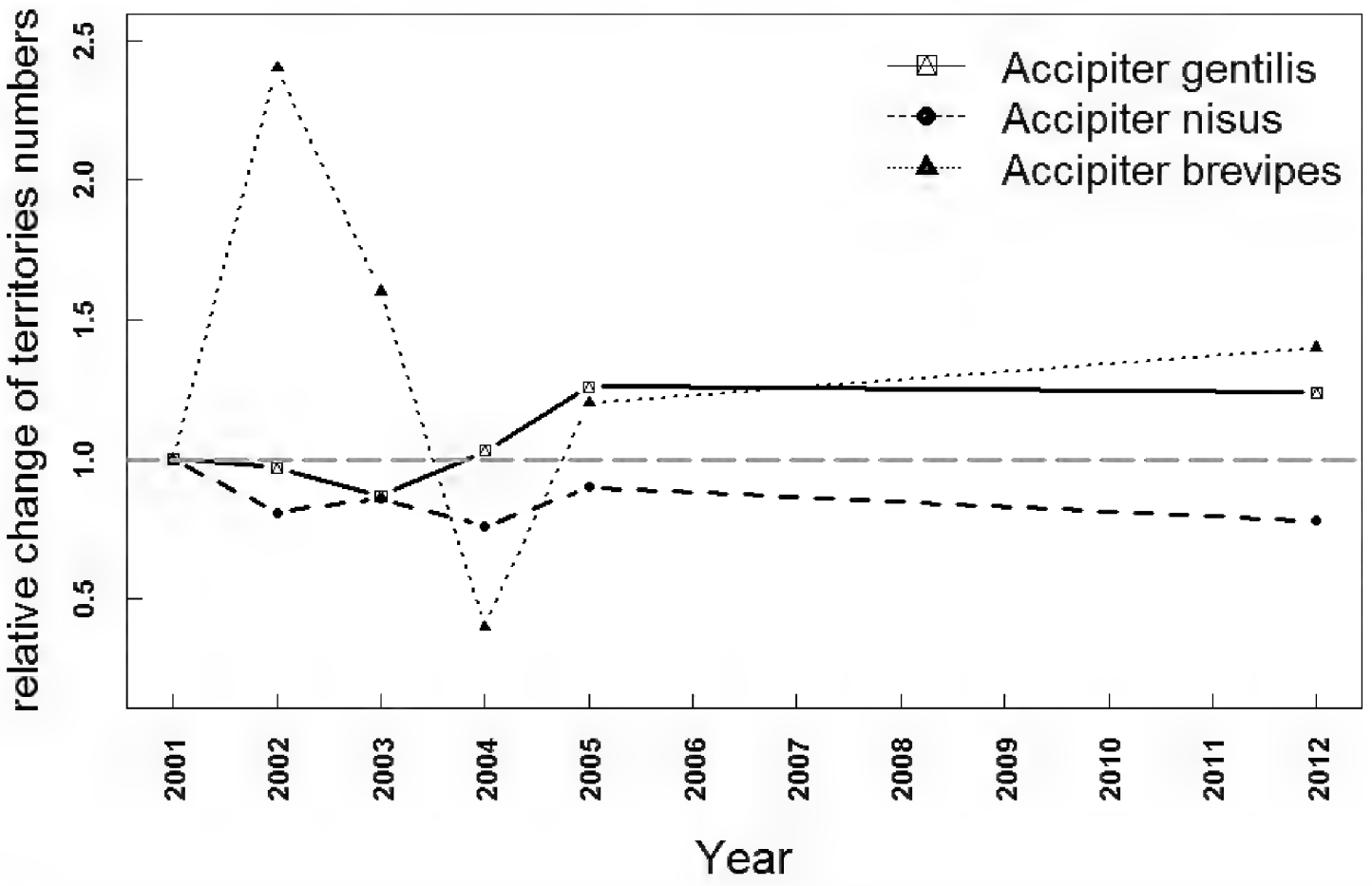


Figure 4. Relative variation in the number of territories of hawks in Dadia-Lefkimi-Soufli National Park during the six Systematic Raptor Monitoring surveys (March to August 2001–2005 and in 2012).

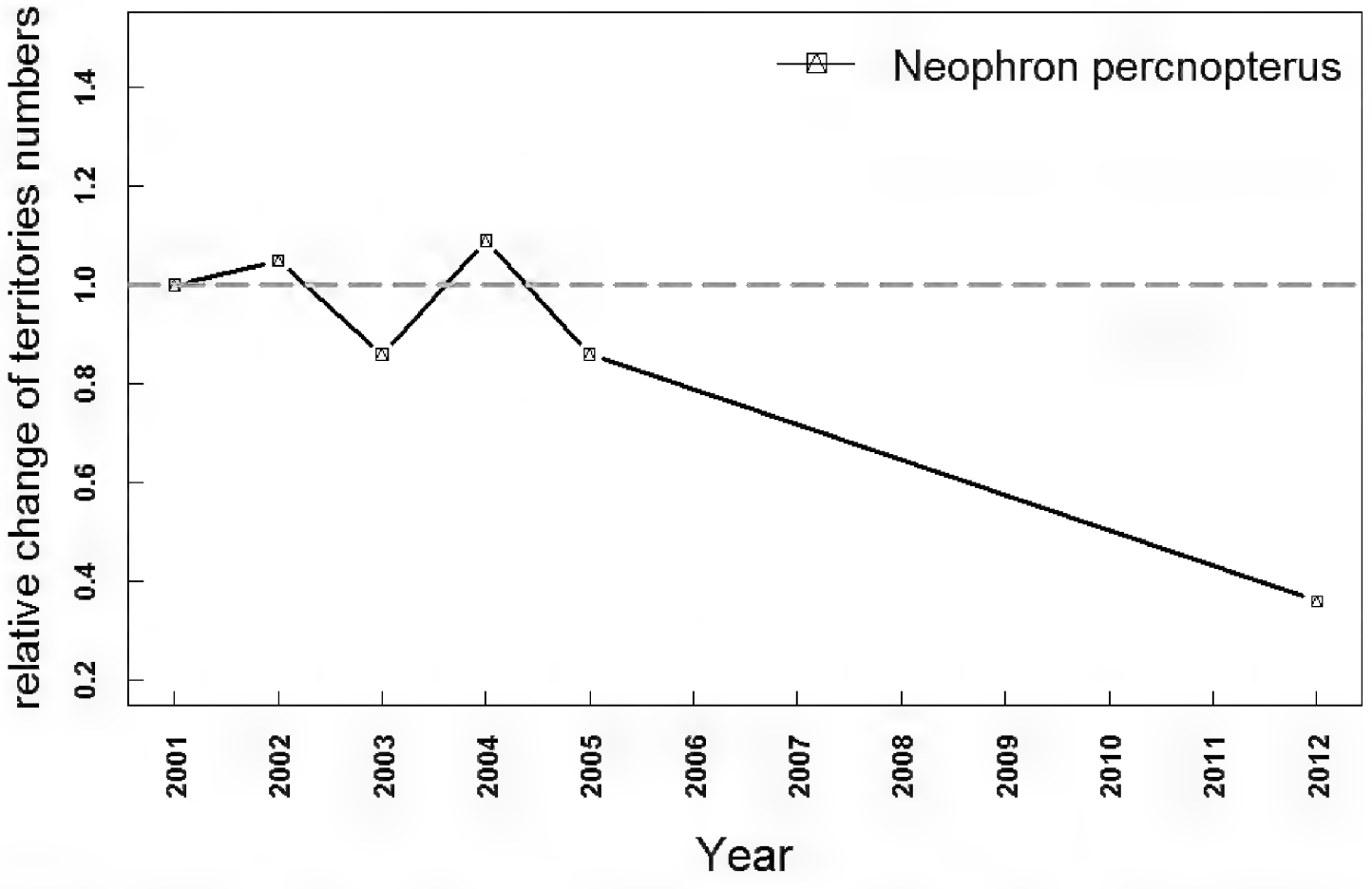
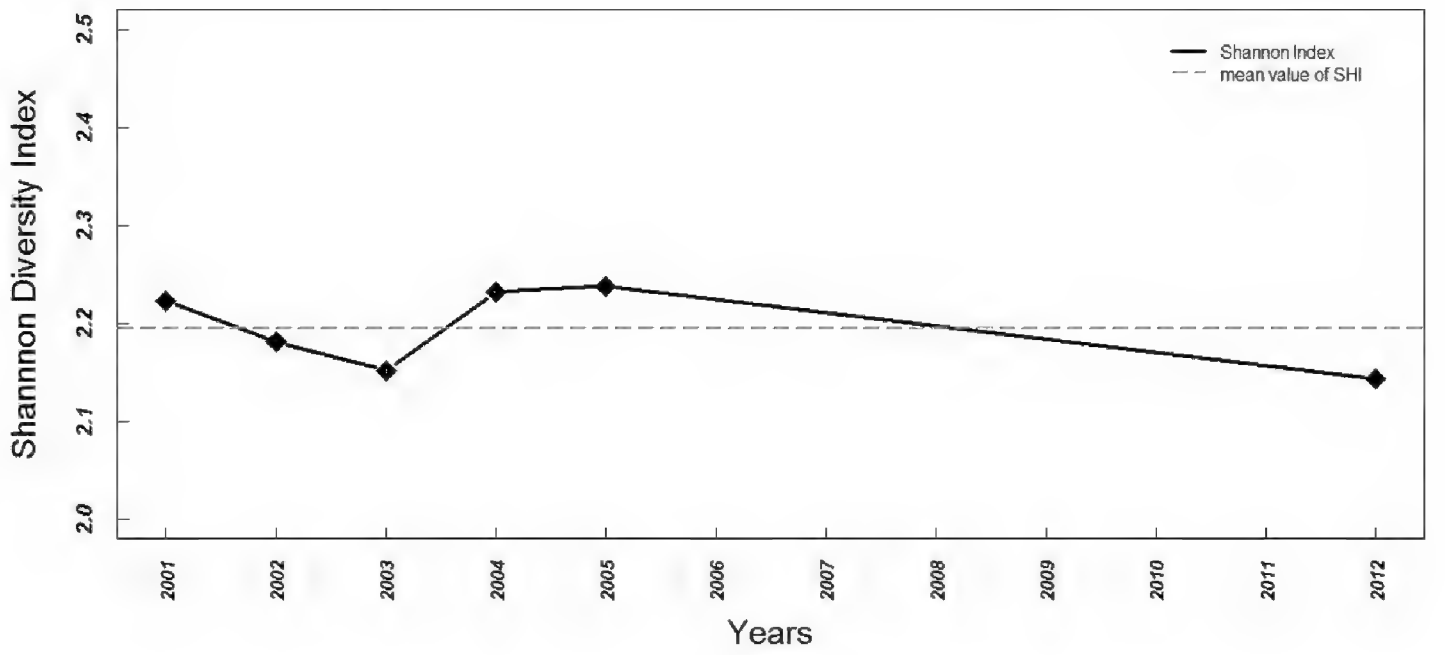
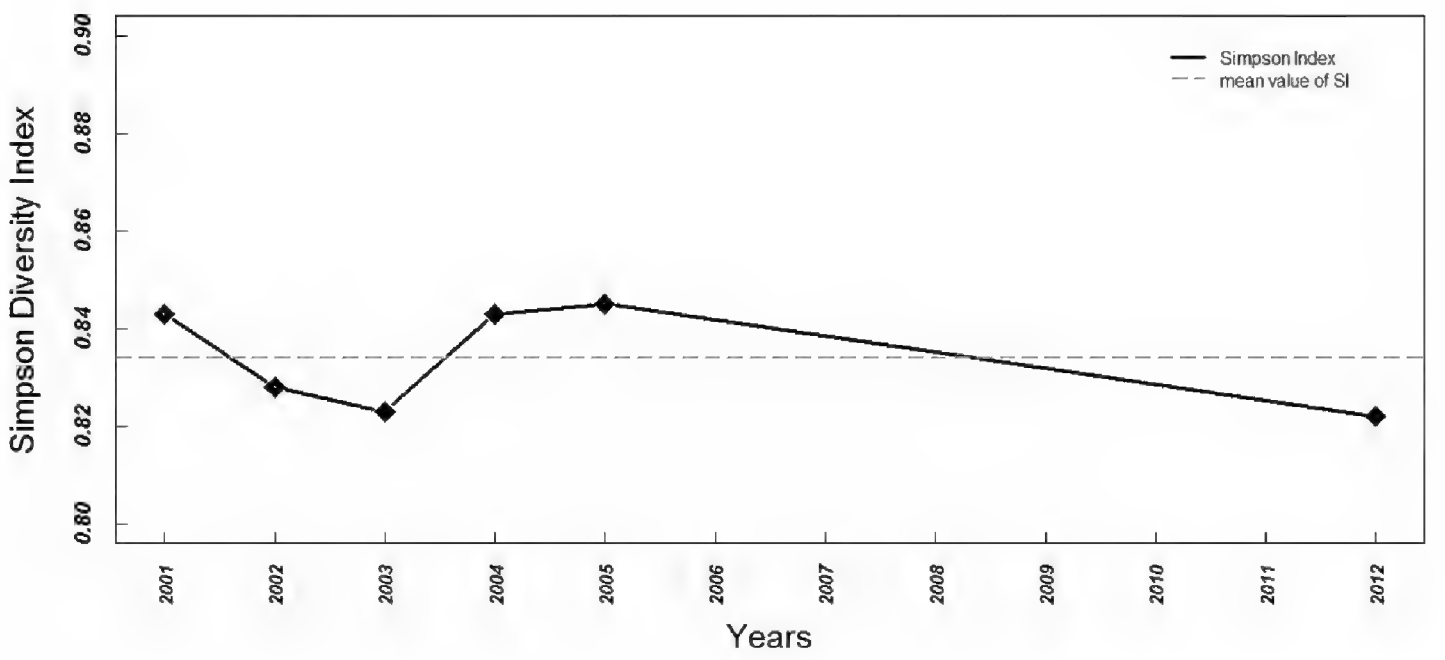


Figure 5. Relative variation in the number of territories of Egyptian vultures in Dadia-Lefkimi-Soufli National Park during the six Systematic Raptor Monitoring surveys (March to August 2001–2005 and in 2012).





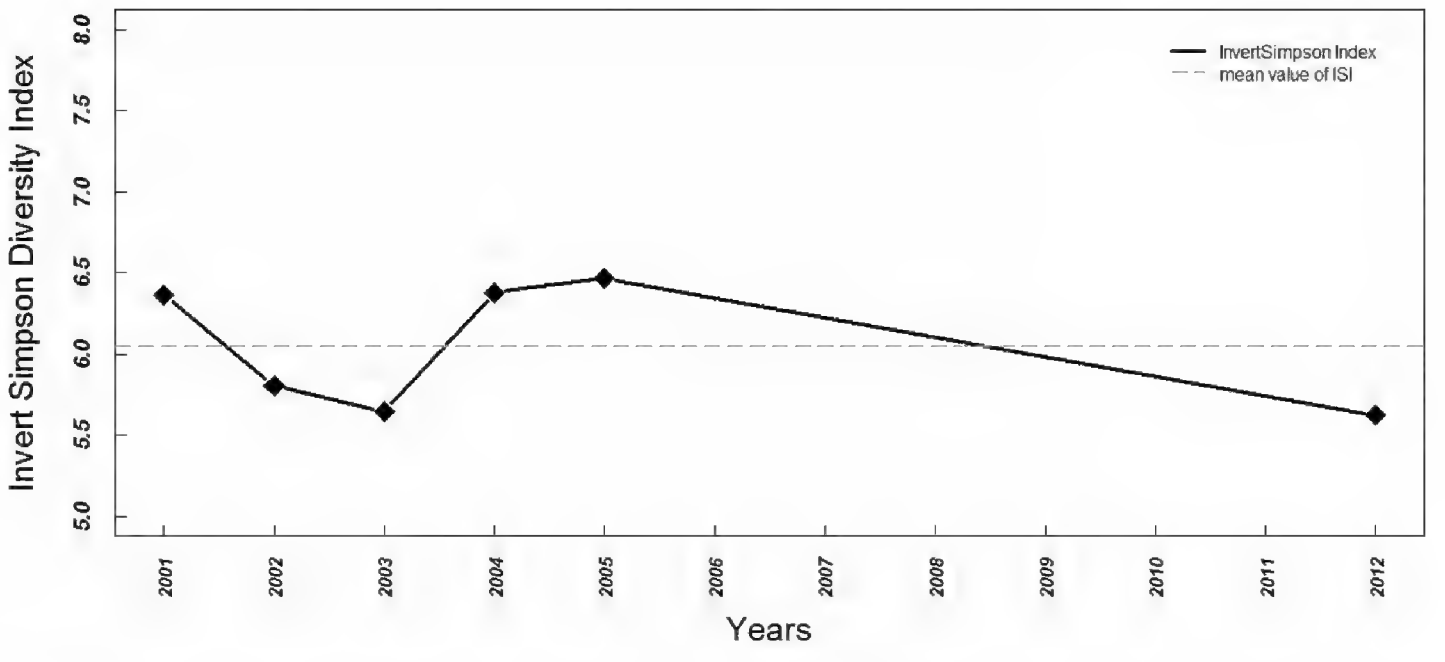


Figure 6. Diversity of raptor assemblages in Dadia NP from 2002 to 2012. Variation in Shannon, Simpson and Invert-Simpson indices is shown.

A further two species displayed moderate increases; namely, the Western marsh harrier and the Eurasian hobby. Four species showed marginal upward trends; namely, the Peregrine falcon, the Levant sparrowhawk, the Booted eagle and the Lesser-spotted eagle. Two species displayed moderate decreases; namely, the Golden eagle and the Long-legged buzzard. (See Table 4 for details)

Models of population trends

The population trends of 14 raptors were modelled. These species had a continuous presence, with active territories in the study area across all survey years (Table 3).

Although the MK test did not reveal statistically significant monotic trends, it provided valuable information on species trends (positive or negative), depending on the sign of the Sen slope value. This result was obtained due to the time series being short. Furthermore, a monotonic line cannot always fit significant fluctuations. In comparison, the more flexible GAMs confirmed that time had a significant effect on population change, with the preliminary trend for the study period being graphically presented using the smoothing technique.

The Short-toed eagle was the only eagle with an increasing trend. The MK test showed an upward trend (though not significant), whereas the GAM showed a significant relative change in the number of territories over time, with a good fit (Table 3, Figure 7a, b). The Golden eagle occupied the same number of territories at the first and last census (Figure 7c, d), presenting very little overall change in variation with respect to the other eagles (Tables 2, 3 and 4). The Lesser-spotted eagle and Booted eagle had slightly higher relative variance in the number of territories by 2012 (Tables 2 and 4), attaining positive M\K slopes. GAMs for the two species of eagles ($t=33.291$, $p<0.0001$ and $t=45.54$, $p<0.0001$ respectively) indicated significant variation over time. The Lesser-spotted and Booted eagles (Figure 8a, b, c, d) had a relatively stable population, even when considering the small overall change in variation (Table 4). However, the Lesser-spotted eagle exhibited a noticeable decline in 2012 (Figure 8a).

With respect to buzzards, only the Common buzzard had a stable trend (MK: tau= 0.066, p=1). The Long-legged buzzard and Honey buzzard showed decreasing MK slopes (Sen slope: -0.166 and -2.6, respectively). The variation in the number of Buzzard territories versus monitoring years was highly significant, with a good fit when using GAMs (Table 3, Figure 9a, b). The Honey and Long-legged buzzards displayed decreasing population trends, with a strong decline being detected for the Honey buzzard (Figure 9c–f).

The trend recorded for hawks was significant when using GAMs (Northern goshawk: $t=69.240$, $p<0.01$, Eurasian sparrowhawk: $t=24.292$, $p<0.0001$, Levant sparrowhawk: $t=14.990$, $p<0.05$), with a robust fit (Table 3) which was attributed to the significant effect of time on their inter-annual variation (Figure 10a–f). Only the Northern goshawk had a positive upward slope (Sen slope: 1.25) in its population trend (tau=0.467, p=0.259) with a robust fit in GAM (Figure 10a, b). The Levant sparrowhawk had no clear trend after 2005, leading to a negative, non-significant MK slope,

Table 3. Generalised Additive Models fitting the Systematic Raptor Monitoring values for each survey year of the number of raptor territories in Dadia-Lefkimi-Soufli National Park (March to August 2001–2005 and in 2012). Results of Linear GAMs and GAMs with cubic and cyclic cubic smoothing splines are shown.

Species of raptors	**Linear GAM** *Family: Gaussian* *Link function: Identity*				**GAM cr** Cubic regression smoothing splines *Family: Gaussian* *Link function: Identity*				**GAM ccr** Cyclic cubic regression smoothing splines *Family: Gaussian* *Link function: Identity*			
	R^2 adj	*Deviance explained*	*GCV*	*AIC*	*R^2 adj*	*Deviance explained*	*GCV*	*AIC*	*R^2 adj*	*Deviance explained*	*GCV*	*AIC*
EAGLES												
Circaetus gallicus	-0.072	14.2%	19.729	36.05	0.998	100%	0.180	-2.74	0.996	99.9%	0.2685	-0.34
Aquila chrysaetos	-0.25	0.02%	1.015	18.25	0.131	43.1%	0.861	16.32	0.244	54%	0.807	15.51
Clanga pomarina	-0.215	2.82%	7.045	29.87	0.477	67.6%	3.921	25.09	0.375	61.6%	4.728	26.16
Aquila pennata	0.078	26.3%	2.039	22.43	0.078	26.3%	2.039	22.43	0.032	3.25%	1.712	22.06
BUZZARDS												
Buteo buteo	-0.2	3.99%	99.626	45.77	0.688	92.99%	91.541	35.85	0.676	92.7%	95.525	36.05
Buteo rufinus	0.47	57.6%	0.556	14.64	0.911	96.8%	0.209	3.52	0.911	96.7%	0.198	3.63
Pernis apivorus	0.629	70.4%	13.879	33.94	0.852	96.1%	17.003	27.13	0.629	70.4%	13.879	33.94
SPARROWHAWKS												
Accipiter gentilis	0.369	49.5%	8.303	30.861	0.942	98.5%	2.406	15.132	0.629	70.4%	13.879	33.943
Accipiter nisus	0.078	26.3%	14.327	34.13	0.078	26.3%	14.329	34.13	-0.019	-1.95%	12.683	34.08
Accipiter brevipes	-0.243	0.58%	5.157	28.00	0.893	97.8%	1.713	11.13	0.887	97.6%	1.808	11.48
FALCONS												
Falco tinnunculus	-0.092	12.6%	27.32	38.00	0.998	99.9%	0.231	-0.66	0.998	99.9%	0.210	-0.70
Falco subbuteo	0.015	21.2%	7.189	29.99	0.015	21.2%	7.189	29.99	0.005	0.5%	5.805	29.39
Falco peregrinus	0.24	39.2%	1.368	20.04	0.24	39.2%	1.368	20.04	0.249	40.6%	1.367	19.99
VULTURES												
Neophron perncopterus	0.801	84.1%	2.551	23.78	0.819	86.6%	2.495	23.32	0.813	85.8%	2.526	23.50
TOTAL TERRITORIES												
Total number of territories in Dadia NP	-0.241	0.71%	436.1	20.04	0.903	98%	130.97	37.16	0.897	97.8	139.82	37.55

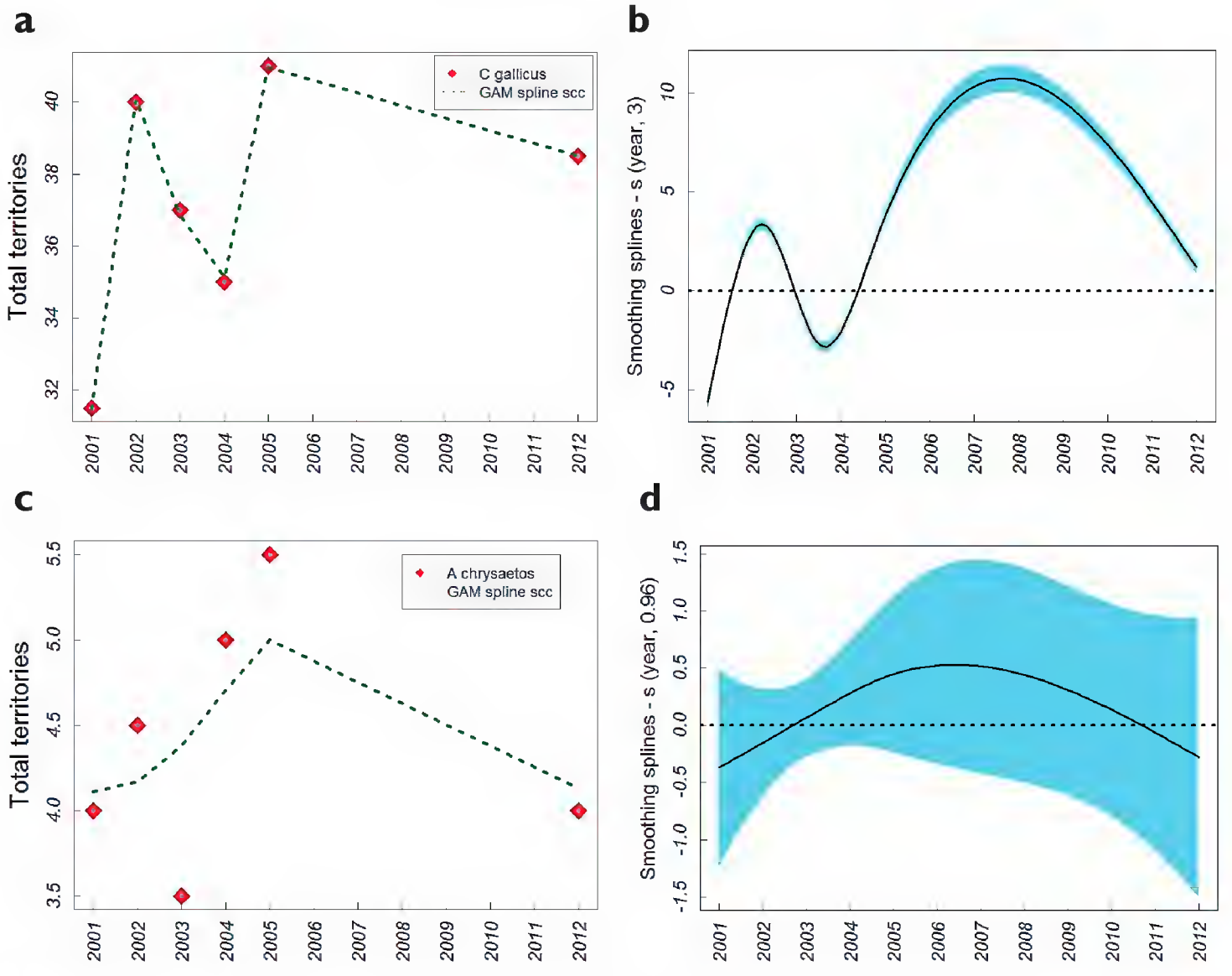


Figure 7. Inter-annual variation in the numbers of territories for Short-toed eagle and Golden eagle in Dadia-Lefkimi-Soufli National Park fitting Generalised Additive Models. Population trend modelling is also shown for each species, with cyclic cubic regression (cc) splines used as smoothing terms. **a** Variation in the number of Short-toed eagle territories fitting a GAM **b** Predictive GAM for the Short-toed eagle with smoothed terms (cc splines) **c** Variation in the number of Golden eagle territories fitting a GAM **d** Predictive GAM for the Golden eagle with smoothed terms (cc splines).

but it had a robust fit in GAM of R^2adj=0.893. This equation defined the effect of time in this short variation cycle, with uncertain fluctuations (Figure 10e, f). The number of Eurasian sparrowhawk territories decreased from 36 to 28 (Figure 10c, d).

The Common kestrel had a negative population trend. The MK slope was not significant, but positive for this species (tau= 0.138, p=0.848). This result was possibly due to a strong increase during the initial years of monitoring (Figure 11a, Table 3), followed by the lowest value being obtained in the final year, indicating a possible negative population trend (Figure 11a, b). The Eurasian hobby showed a positive MK slope (tau= 0.333, p=0.452). This trend was probably due to the highest value being obtained in the final monitoring year (Tables 2 and 4). The Peregrine falcon had a positive MK slope that was marginally significant (tau= 0.745, p=0.069) and a significant GAM (t=6.428, p<0.05). A low adjustment GAM R^2 value fitted through the Peregrine falcon data, demonstrating an increasing trend for the species. The estimated number of Peregrine falcon territories increased from two in 2001 to 3.5 in 2012 (Figure 11e, f).

Table 4. Relative frequency in the number of raptor territories in Dadia-Lefkimi-Soufli National Park in 2001 and in 2012. Percentages were calculated from the total number of territories per year. Percentage change variation was based on the difference between the first and the last year of the Systematic Raptor Monitoring scheme. Absolute territory numbers per species are shown for both 2001 and 2012. Data are shown in decreasing value-order with respect to the overall percentage variation change.

Birds of prey species	Absolute number of territories in 2001	Absolute number of territories in 2012	Relative territory frequency in 2001 (%)	Relative territory frequency in 2012 (%)	Percentage (%) variation change between 2001 and 2012
Buteo buteo	110	122.5	32.93	35.92	2.99
Circaetus gallicus	31.5	38.5	9.43	11.29	1.86
Accipiter gentilis	19	23.5	5.69	6.89	1.20
Circus aeruginosus	0	3	0.00	0.88	0.88
Falco subbuteo	6.5	9.5	1.95	2.79	0.84
Falco peregrinus	2	3.5	0.60	1.03	0.43
Accipiter brevipes	2.5	3.5	0.75	1.03	0.28
Aquila pennata	20.5	21.5	6.14	6.30	0.17
Clanga pomarina	17	17.5	5.09	5.13	0.04
Aquila chrysaetos	4	4	1.20	1.17	-0.02
Buteo rufinus	3.5	1.5	1.05	0.44	-0.61
Falco tinnunculus	15.5	11	4.64	3.23	-1.41
Neophron percnopterus	11	5	3.29	0.47	-1.83
Accipiter nisus	36	28	10.78	8.21	-2.57
Pernis apivorus	28.5	15.5	8.53	4.55	-3.99

Out of all documented raptor species, the Egyptian vulture demonstrated the greatest population decline (Tables 2–4, Figure 12a, b). This species had a negative slope that was marginally significant (MK: tau = -0.412, p=0.07). When the time series was extended to include 2000 to 2016 (WWF Greece, unpublished data), the Egyptian vulture showed a highly significant MK negative trend (tau=-0.62, p< 0.001).

With respect to the overall number of raptor territories, a small overall increase was detected (Table 2). This increase was possibly influenced by an increase in the number of Short-toed eagles and Common buzzards. Overall, the territories fit a significant GAM model vs time, with high R^2 adjustment (Table 3). The overall trend for 2001–2012 is shown in Figure 13a, b.

Discussion

Raptor monitoring as a conservation tool

Monitoring is an essential tool for effective nature conservation and management. Both long-term trends and the present status of populations allow sound management programmes to be formulated (Kirk and Hyslop 1998, Saurola 2008). In particular,

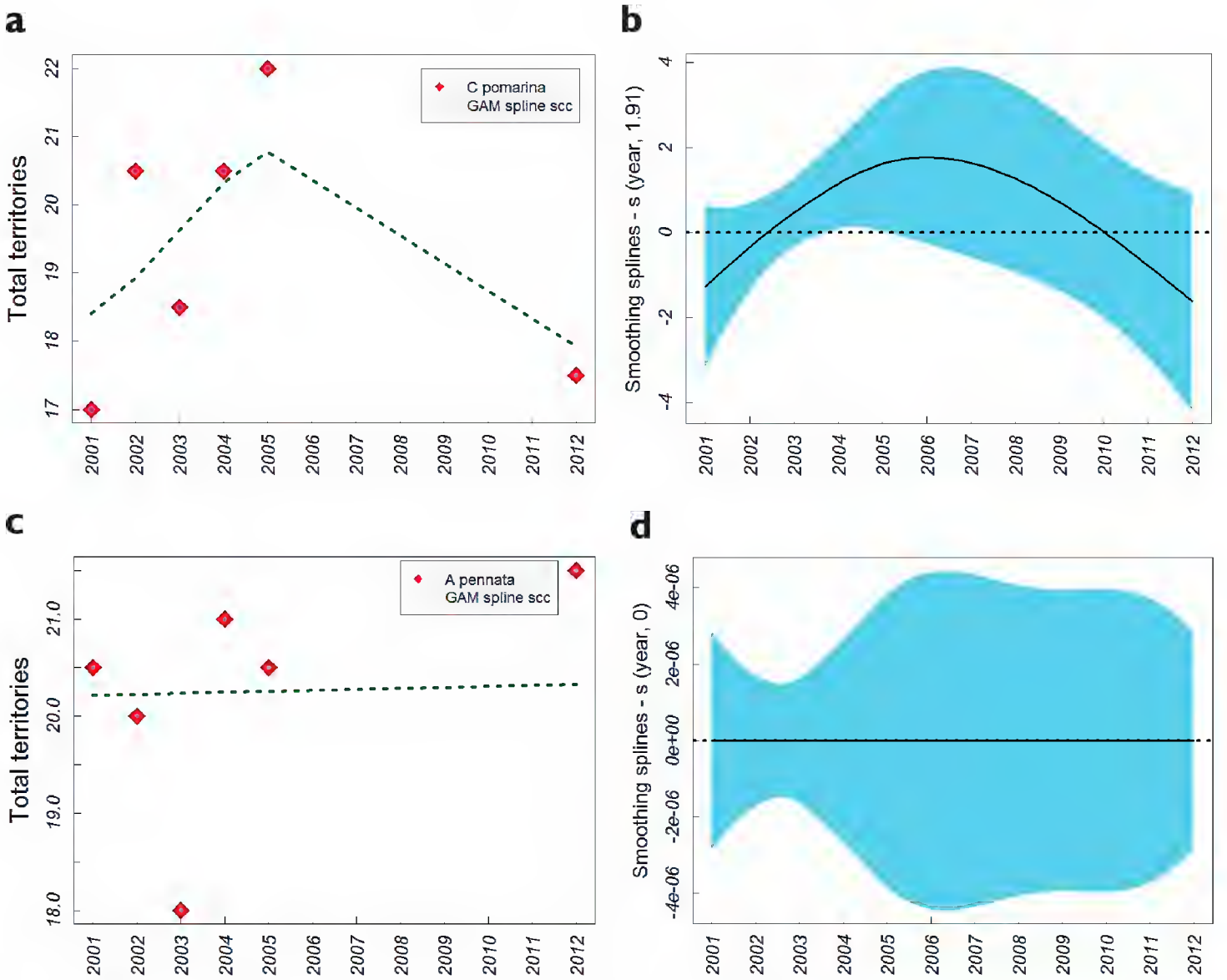


Figure 8. Inter-annual variation in the numbers of territories for Lesser-spotted eagle and Booted eagle territories in Dadia-Lefkimi-Soufli National Park fitting Generalised Additive Models. Population trend modelling is also shown for each species with cyclic cubic regression (cc) splines used as smoothing terms. **a** Variation in the number of Lesser-spotted eagle territories fitting a GAM **b** Predictive GAM for the Lesser-spotted eagle with smoothed terms (cc splines) **c** Variation in the number of Booted eagle territories fitting a GAM **d** Predictive GAM for the Booted eagle with smoothed terms (cc splines).

forest-dwelling raptors are difficult to monitor, as they are widely dispersed and are difficult to detect, due to vegetation, forest canopy and land topography (Fuller and Mosher 1987). Thus, monitoring the population dynamics of raptors involves high requirements in personnel, time and cost (Catsadorakis 1994). Yet, the early detection of causes in population fluctuation provides the opportunity for "on-time" management decisions (Vos et al. 2000). The EU has set as one of its key objectives "to conserve most important species and habitats," including a large proportion of Europe's raptor species (Kovacs et al. 2008). At present, 64% of the 56 raptor and owl species that occur in Europe have an unfavourable conservation status (Kovacs et al. 2008).

Globally, the monitoring effort of raptors tends to focus on nest location and the observation of individuals (Fuller and Mosher 1987), this being a highly resource demanding process. In comparison, WWF Greece organised a different SRM approach which has been implemented in Dadia NP since 2001. This scheme involves monitor-

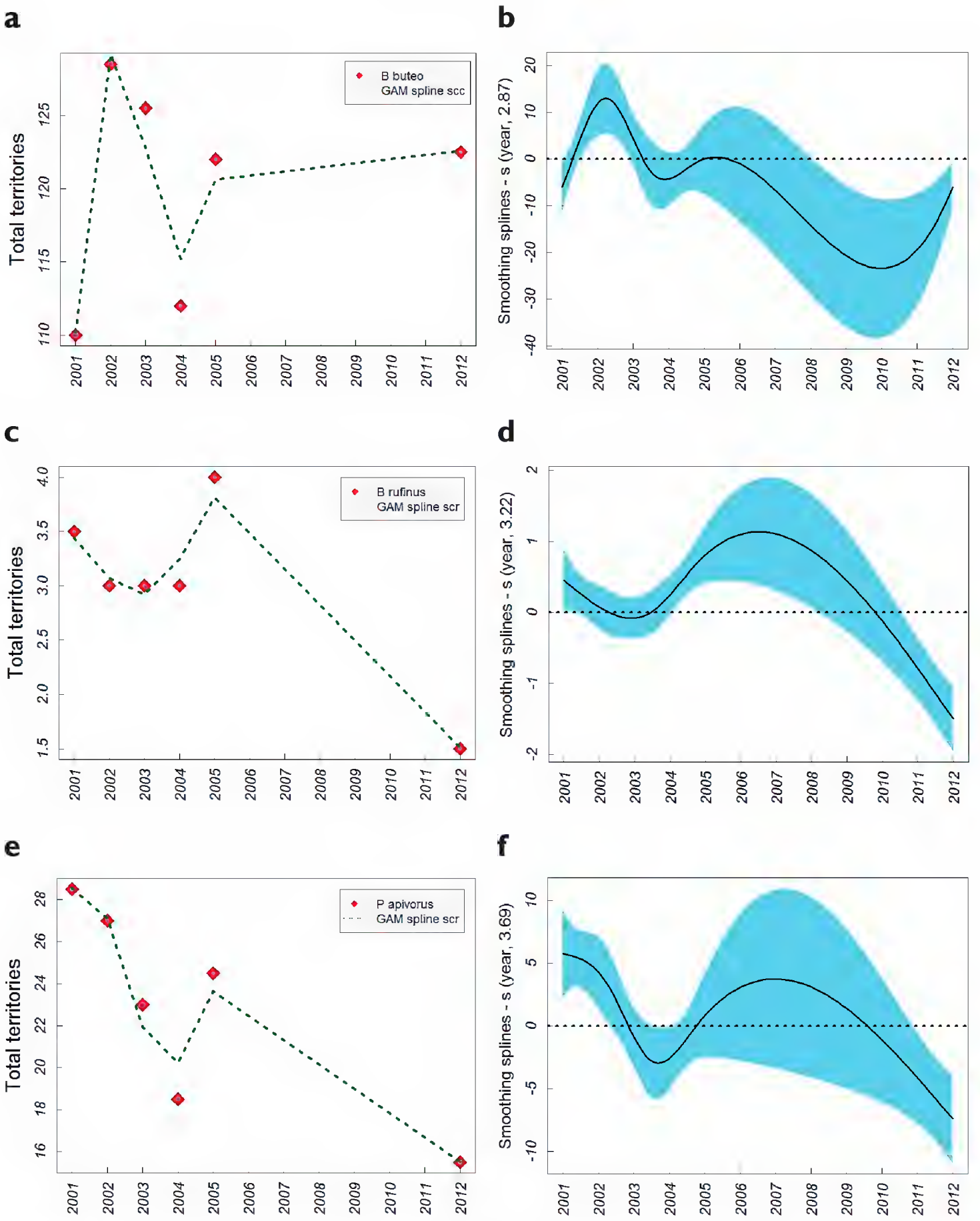


Figure 9. Inter-annual variation in the number of buzzard territories in Dadia-Lefkimi-Soufli National Park fitting Generalised Additive Models. Population trends modelling is also shown for each species with cubic regression (cr) or cyclic cubic regression (cc) splines used as smoothing terms, depending on lowest AIC in each case. **a** Variation in the number of Common buzzard territories fitting a GAM **b** Predictive GAM for the Common buzzard with smoothed terms (cc splines) **c** Variation in the number of Long-legged buzzard territories fitting a GAM **d** Predictive GAM for the Long-legged buzzard with smoothed terms (cr splines) **e** Variation in the number of Honey buzzard territories fitting a GAM **f** Predictive GAM for Honey buzzard with smoothed terms (cr splines).

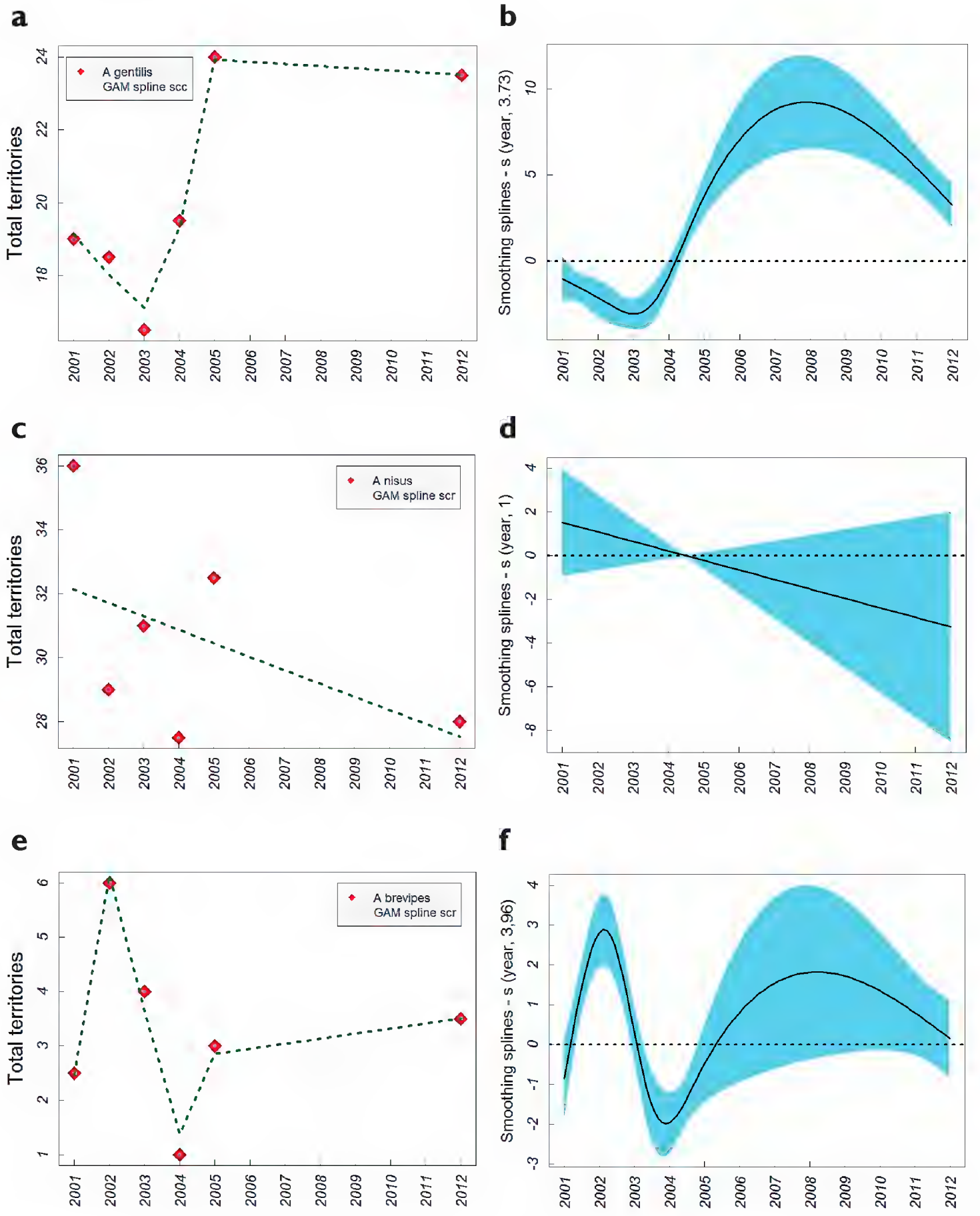


Figure 10. Inter-annual variation in the number of hawk territories in Dadia-Lefkimi-Soufli National Park fitting Generalised Additive Models. Population trend modelling is also shown for each species with cubic regression (cr) or cyclic cubic regression (cc) splines used as smoothing terms, depending on lowest AIC in each case.**a** Variation in the number of Northern goshawk territories fitting a GAM **b** Predictive GAM for the Northern goshawk with smoothed terms (cc splines) **c** Variation in the number of Eurasian sparrowhawk territories fitting a GAM **d** Predictive GAM for the Eurasian sparrowhawk with smoothed terms (cr splines) **e** Variation in the number of Levant sparrowhawk territories fitting a GAM **f** Predictive GAM for the Levant sparrowhawk with smoothed terms (cr splines).

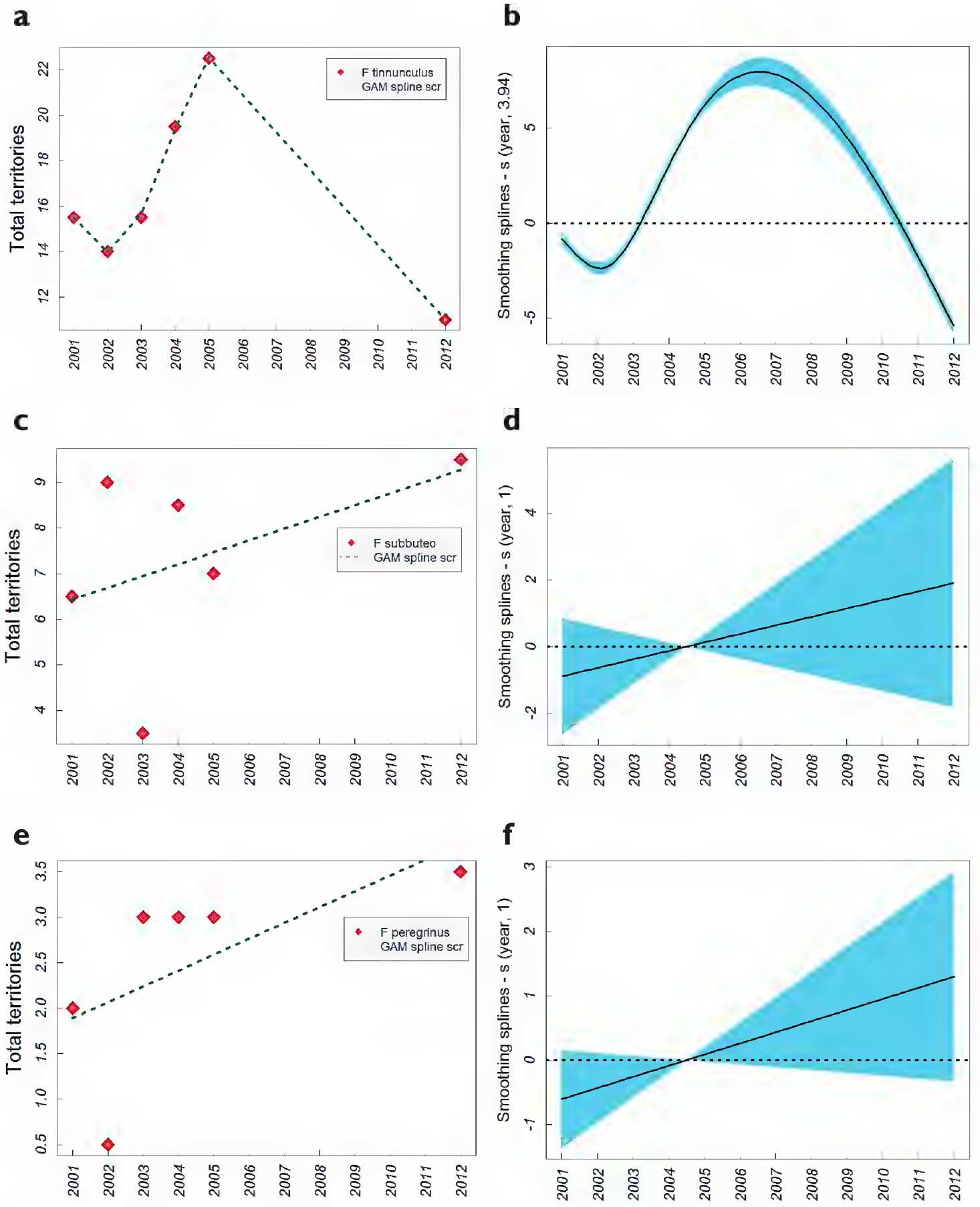


Figure 11. Inter-annual variation in the number of falcon territories in Dadia-Lefkimi-Soufli National Park fitting Generalised Additive Models. Population trends modelling is also demonstrated for each species with cubic regression (cr) splines used as smoothing terms. **a** Variation in the number of Common kestrel territories fitting a GAM **b** Predictive GAM for the Common kestrel with smoothed terms (cr splines) **c** Variation in the number of Eurasian hobby territories fitting a GAM **d** Predictive GAM for the Eurasian hobby with smoothed terms (cr splines) **e** Variation in the number of Peregrine falcon territories fitting a GAM **f** Predictive GAM for the Peregrine falcon with smoothed terms (cr splines).

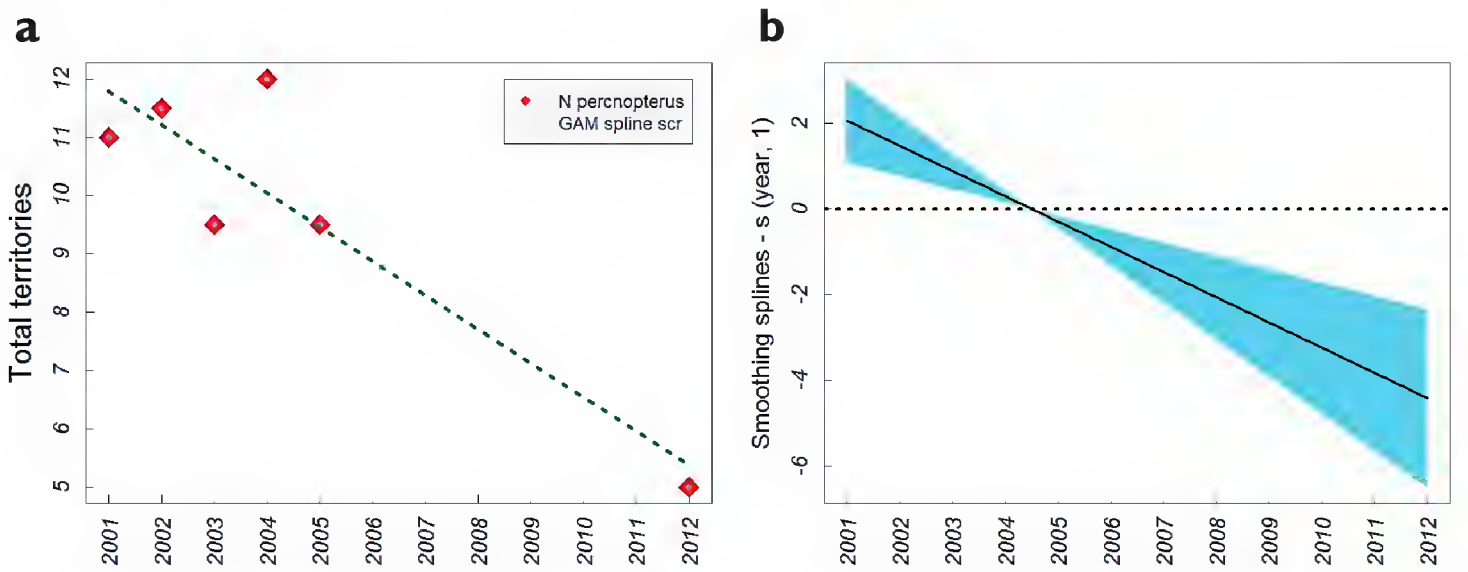


Figure 12. Inter-annual variation in the number of Egyptian vulture in Dadia-Lefkimi-Soufli National Park fitting Generalised Additive Models. Population trend modelling is also shown for the species with cubic regression (cr) splines used as smoothing terms. **a** Variation in the number of Egyptian vulture territories fitting a GAM **b** Predictive GAM for the Egyptian vulture with smoothed terms (cr splines).

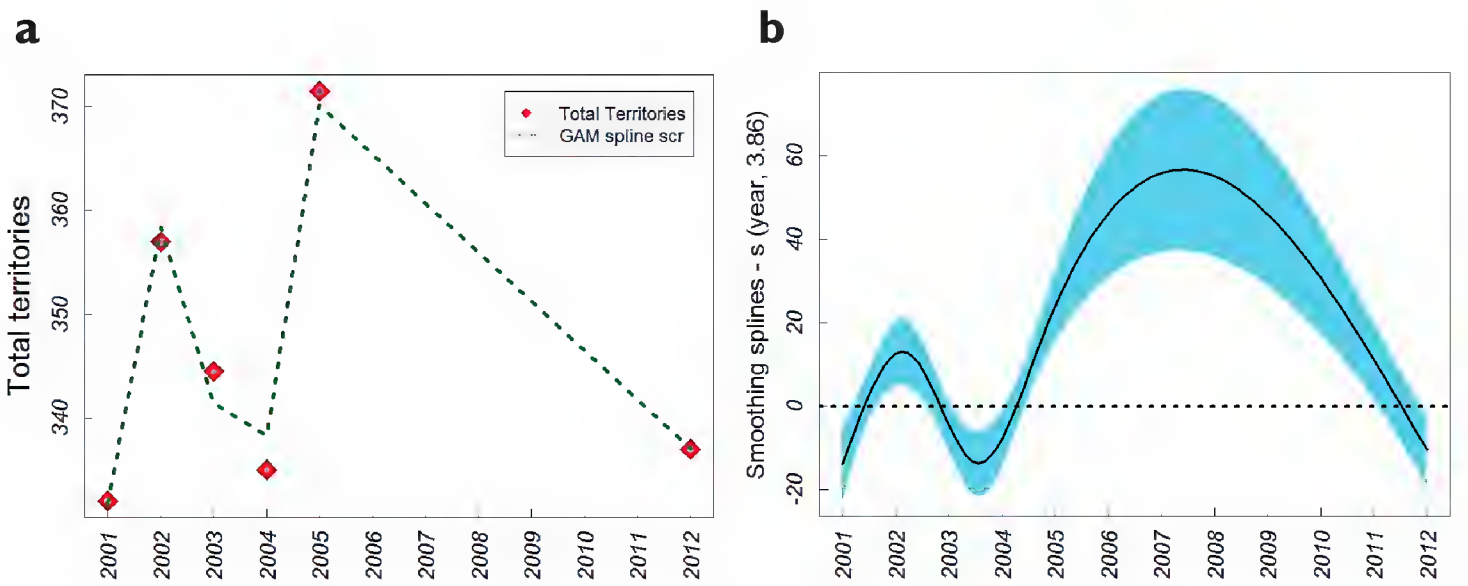


Figure 13. Inter-annual variation in the number of overall raptor territories in Dadia-Lefkimi-Soufli National Park fitting Generalised Additive Models. Population trends modelling is also demonstrated for the whole number of territories with cubic regression (cr) splines used as smoothing terms. **a** Variation in the number of overall raptor territories fitting a GAM **b** Predictive GAM for overall raptor territories with smoothed terms (cr splines).

ing and analysing inter-annual variations in breeding territories and is a useful and cost-effective tool for tracking raptor population trends (Katzner et al. 2007, Carrete et al. 2002, Poirazidis et al. 2009). Furthermore, the current study establishes a reproducible, long-term evaluation protocol for the raptor population status. The SRM was conducted from March to August (breeding period) in 2001–2005 and in 2012. Thus, the monitoring effort in Dadia NP is at an early stage when compared with other long-established European monitoring schemes (Crick et al. 1990, Gil-Sanchez et al. 2004, Stjernberg et al. 2006, Saurola 2008, Aradis and Andreotti 2012, Vrezek et al. 2012, Gamauf 2012, Galushin 2012, Spasov et al. 2012, Urcun 2012, Sanchez-Zapata 2012, Palma 2012, Vermeersch and Paquet 2012, Velevski et al. 2015).

Diversity of the raptor assemblage

A total of 27 diurnal raptor species were recorded in Dadia NP during the breeding season, 20 of which breed in the NP regularly. Three different diversity indices calculated for the raptor assemblage (Shannon, Simpson, Invert-Simpson) showed that raptors exhibited high diversity in the NP. These values had the highest ranking compared to values for raptors in other areas (Colwel 2009), reaffirming the high value of Dadia NP for raptors, where 36 of the 38 raptor species in Europe have been observed (Hallman 1979, Catsadorakis and Källander 2010).

However, over the 12-year period (from SRM1 to SRM 6), raptor diversity declined. All diversity values reached their lowest point in the final SRM year (2012) (Figure 6). Over this period, the number of the dominant Short-toed eagle and the Common buzzard (Figures 1 and 2), represented more than 50% of observed individuals and territories, along with a parallel decrease in less abundant species, such as the Golden eagle, Long-legged buzzard, Honey buzzard and Eurasian sparrowhawk (Tables 1 and 4). These trends are probably explained by changes in environmental factors, such as the landscape homogenisation (Adamakopoulos et al. 1995, Triantakonstantis et al. 2006), negatively impacting less competitive species that are dependent on specialised spaces in the forest ecosystem, leading to their being replaced by more common (competitive) species. Moreover, other anthropogenic factors are also driving the decline in raptor numbers in this region, examples including illegal poisoning and collisions with wind turbines (Kafetzis et al. 2017, Skartsi et al. 2014, Saravia et al. 2016, Ntemiri and Saravia 2016, Kret et al. 2016, Vasilakis et al. 2017).

However, it is also important to determine whether this decline in overall raptor diversity is actually due natural fluctuation processes or whether there is actually a consistent decline in rare and more specialist species requiring management action. A definite answer could only be provided following the long-term implementation of the SRM scheme. Such information would clarify whether the natural fluctuation process will be reversed or whether the decrease in diversity will continue due to intra-specific competition, landscape change and anthropogenic pressure. In particular, species with smaller numbers, less competitive mechanisms and more specialised habitat requirements might be at risk (Sanchez-Zapata and Calvo 1999, Juliard et al. 2006).

Overall, Dadia NP has a generally stable number of territories, with a small annual increase (Figure 13a, b). A total of 346–350 breeding territories was documented for all species combined in Dadia NP, with a fluctuation of ±40, possibly defining the limits of a natural fluctuation across the years. The Short-toed eagle and the Common buzzard (Figures 7a, b, 9a, b) were the most common (and abundant) raptor species in the region, with the trends for these two species shaping the detected variation of all breeding territories in the NP. Thus, this measure must be treated with caution, as the overall stability in territories for all species combined fails to account for the detected decline in rare and more specialist species. Of note, 19 of the 23 raptor represent less than 3% relative frequency of the records with respect to all recorded observations per year (Table 1).

Raptor population trends and possible effects of land use and landscape change

The Short-toed eagle is a specialist predator with a narrow niche diet of reptiles (Bakaloudis 1998), along with specific habitat needs for nesting (Bakaloudis 2001). Within the NP, forests have begun encroaching on abandoned agricultural land, increasing the extent of closed canopy (Adamakopoulos 1995, Poirazidis et al. 2011) and negatively impacting biodiversity (Zakkak 2014). This phenomenon could negatively impact species that need open areas to forage. Yet, the Short-toed eagle has maintained a stable population (even with a small increase) in this study area (Figure 7a, 7b). A possible reason for this might be that edge-habitats, which are necessary for reptile diversity and successful hunting (Sanchez-Zapata and Calvo 1999), have not reached critical levels for the species due to the presence of a network of tertiary roads that intersect the area. The Short-toed eagle population was generally stable, with a natural variation of 37±6 territories which might represent the stability threshold for the species in Dadia NP (Figure 7b).

With respect to eagles, the Booted eagle demonstrated robust population stability, whereas the Golden eagle and Lesser-spotted eagle exhibited contrasting trends. Both species exhibited overall stability, with similar values being obtained in the first and last SRM years; however, values fluctuated irregularly in the intervening years. In particular, 2003 was a poor year for eagle abundance in Dadia NP (Figures 7a, c, 8a, c), possibly due to climatic factors influencing the availability of prey for the raptors (Terraube et al. 2011, Wichmann et al. 2013). Alternatively, this decline might be a regular repetitive pattern which could only be detected through long-term monitoring. The Booted eagle had overall high abundance values for all years, except 2003 and an increase in 2012 (Figure 8c). If 2003 were excluded from the model, the population trend for this species would be clearly positive. The stability threshold of Booted eagles in the region is probably around 20 occupied territories on average. This raptor is generally scarce; yet, its population has somehow increased in Western Europe. This species is particularly sensitive to the management of forest ecosystems and co-existence with agricultural land (Suárez et al. 2000).

The Golden eagle and Lesser-spotted eagle presented identical trends (Figures 7d and 8b), with the numbers of both declining in 2003. These increasing fluctuations over the first 5 years, along with the large decrease in 2012, create an uncertainty about whether this is a regular fluctuating trend or if the decrease in 2012 requires immediate mitigating action.

A recent, noticeable, change in modern agricultural practices in the region of Dadia NP is the monoculture of Helianthus (*Helianthus annuus*), due to contract agriculture. Contract farming involves agricultural production being carried out on the basis of an agreement between the buyer and farm producers, where the buyer specifies the quantity required and the price, with the farmer agreeing to deliver at a future date. Similar changes in Estonia have caused problems for eagles that forage in open areas during the breeding period, these eagles decreasing due to Helianthus farming, including the Lesser-spotted eagle (Väli et al. 2017). Thus, the large decrease in the Lesser-spotted

eagle population between 2005 and 2012 (Figure 8a, b) might reflect the negative effect of landscape changes in relation to this crop in Dadia NP. Poirazidis et al. (2010) showed that the Lesser-spotted eagle population had been stable over the last 25 years in Dadia NP; however, there was a marked change in the elevation at which it nested. For instance, only 50% of pairs bred below 100m in the 1970s (Hallmann 1979), whereas this number had risen to 67% by 2001. Habitat change is the major driver behind this shift; thus, the change in the distribution of Lesser-spotted eagles in Dadia NP might be related to the decline in open and semi-open habitats in the interior of the forest since the 1950s (Triantakonstantis 2006, Poirazidis et al. 2015). This decline in forest heterogeneity might have also caused the abundance of reptiles and amphibians, which represent an important food source for the Lesser-spotted eagle in DNP, to decline (Vlachos and Papageorgiou 1996).

The Common buzzard is a generalist predator with a broad habitat niche (Rooney and Montgomery 2013, Jankowiak et al. 2015). Large fluctuations in territory numbers were detected in the initial SRM years; however, an increase was detected in 2012 (Figure 9a). The irregular initial fluctuations, along with the gap between fifth and sixth surveys generated high variability (Figure 9b), with more monitoring being required to determine whether this is a regular population trend. Overall, in Dadia NP, Common buzzards occupy an average number of 120 territories.

The Honey buzzard and Long-legged buzzard are more specialist species and demonstrated negative population trends. Interestingly, in the bordering regions of Bulgaria, the Long-legged buzzard has not undergone any major decline for 20 years (Iankov 2007). In contrast, in Dadia NP, the species probably reached low enough numbers for the population to crash in 2012 (Figure 9c). This raptor occupied very few territories in the NP (Table 4). Nonetheless, from 2001 to 2005, its numbers regularly fluctuated around three breeding territories which might be the minimum viable threshold for the species. However, the decrease in territories by 2012 probably indicates a negative population trend driving the Long-legged buzzard below its survival limits in Dadia NP (Figure 9d). Thus, continued monitoring is required to determine whether the population can recover. This decline might be associated with the noticeable decline in nomadic livestock farming between 2000 and 2012. Decreased grazing induced the lower use of open area patches within the forest ecosystem, altering the form of the heterogeneous mosaic in Dadia NP, leading to a parallel increase in the homogeneity index in the region. Consequently, open area foraging raptors lack adequate hunting space.

The Honey buzzard showed the largest population decrease of all the buzzard species in Dadia NP (Table 4). Even though it is a strict forest nesting species, without specific habitat requirements for its nesting sites (Gamauf et al. 2013), the increase in forested area in the region does not seem to have benefitted it. This fact is difficult to explain. Other factors might be suppressing the population, particularly in relation to its migratory habits. For instance, juvenile mortality of up to 50% is thought to occur during the "Sahara crossing" (Strandberg et al. 2009). Furthermore, this species has been subject to more than 30 years poaching in regions of the Mediterranean (Barca et al. 2016). As the species is exhibiting clear negative population trends in the study area

(Figure 9e, f), it is not possible to determine the minimum viable population threshold for this site. Although an average of 24 territories might be a representative threshold, further confirmation is needed.

In contrast to the Eurasian sparrowhawk (Figure 10c, d), hawks, which are also strictly forest dwelling species (Rutz 2006), exhibited stable to increasing populations in Dadia NP. Specifically, the Northern goshawk showed the highest overall percentage variation increase, in terms of occupied territories (Table 4). This increase might have contributed to the decline in the Honey buzzard, due to inter-specific competition. While Honey buzzards do not have specific habitat criteria for nesting sites, they do locate their nests away from Northern goshawks to avoid their young being subject to predation (Gamauf et al. 2013, Hakkarainen et al. 2004). The increase in the closed canopy forest in Dadia NP might have allowed the more agile and competitive Northern goshawk to out-compete the Honey buzzard from optimum forest sites, allowing Northern goshawk numbers to increase to the detriment of Honey buzzard numbers. Twenty territories on average might be the stability threshold for the Northern goshawk in Dadia NP.

The Levant sparrowhawk has a much lower population size in the study region (Table 1), with a relatively stable fluctuation curve (Figure 10f). However, it is difficult to monitor this species because of its cryptic nature and preference for difficult-to- access terrain. Therefore, the short-term monitoring results are not sufficient to determine whether this species demonstrates natural population fluctuations (Figure 10e, f). Only part of this population actually breeds in the NP, as its main breeding territories occur along the riparian ecosystem of the Evros River (Poirazidis, unpublished data) which forms the natural eastern border of the NP on the border with Turkey. The decrease in the numbers of Eurasian sparrowhawk in the region (Figures 10c and 10d) might be explained by several factors, such as abiotic environmental conditions, resource availability, population density and inter/intra-specific interactions (Nielsen and Moller 2006). Competition and resources partitioning might be the primary causes for the population decline of this species, as optimum forest habitat appears to be increasing in Dadia NP.

The Common kestrel was the only falcon to exhibit decreasing trends in the Dadia NP (Figure 11a, b). However, the time-series is too short to make clear conclusions. The Common kestrel is quite abundant in Greece and is one of the most common raptors in the EU; thus, it is not expected for this species to be under pressure. One potential source of pressure might be the increase in Northern goshawks in Dadia NP, due to inter-specific competition and predation on the young (Petty et al. 2003). In comparison, the population trends of the Peregrine falcon and Eurasian hobby are clearly positive (Figure 11c, d, e, f), with numbers increasing in Dadia NP.

One of the most important and emblematic species for the region, the Egyptian vulture, is being subject to distinct decreasing population trends (Figure 12a , b). Successful conservation projects have been implemented throughout the distribution of the species range in Greece and abroad (Oppel et al. 2016) with the support of EU and national funding. However, the future of the species in Dadia NP is uncertain,

with only three breeding pairs remaining at Dadia NP. This decrease has been primarily attributed to illegal poisoning which is a pan-European issue (Hernández and Margalida 2009, Skartsi et al. 2014, Ntemiri and Saravia 2016). In the Balkans, the species has fragmented into six sub-populations, with major problems being poisoning, electrocution, direct persecution and changes in food availability (Saravia et al. 2016). These factors operate at large spatial scales, affecting birds both on breeding grounds and during migration and wintering (Oppel et al. 2017, Velevski et al. 2015). Recent research on radio-tagged birds in the Balkans has demonstrated that high mortality exists in first-time young migrants which die over seas during migration. In this species, inexperienced juveniles follow experienced adults to the foraging grounds; however, as the population shrinks, the number of experienced adults is declining, forcing juvenile birds to migrate without conspecific guidance (Oppel et al. 2015).

Conservation implications for management

A common concept in wildlife populations is that, under situations of pressure, limitation of resources, competition and habitat/landscape change, specialist species are the first to pay the price, due to their inability to adapt to rapid changes and have narrow niches (Ferrer and Negro 2004). In Dadia NP, slow but continuous landscape change has been recorded. The homogeneity index of the forest ecosystem has increased, with the slow disappearance of forest openings, due to the abandonment of traditional and open livestock farming (Triantakonstantis 2006, Poirazidis et al. 2015). In addition, traditional agricultural practices are converting to Helianthus crops which benefit contract-farmers. These two changes are negatively affecting raptors that require open-area habitats to hunt, as well as other species that preferentially inhabit land mosaics. In particular, this change is impacting both specialists in the region and biodiversity in general. While deforestation is a major problem in many countries (Carrara et al. 2015), the ecosystem of the Dadia NP is based on the balanced co-existence of man, forest, land use and livestock farming through a traditional framework that maintained forest clearings. This combination is the key to the success of this region in supporting a highly diverse landscape and biodiversity.

Specialisation is an expected evolutionarily response to habitat stability (in space or time), whereas the generalist strategy is a response to the lack of stability of the environment (Futuyma and Moreno 1988). For instance, Julliard et al. (2006) showed that, within a given habitat category, generalist species tend to aggregate at certain sites, while specialist species tend to aggregate at others. The authors suggested that specialists prefer more stable sites, while generalists the more unstable sites. Thus, the slow homogenisation of the Dadia NP forest is causing the previously balanced ecosystem to enter an unstable situation; consequently, generalists have been increasing in the forest, whereas specialists have been driven away in search of more stable ecosystems. The additional pressures of poisoning, electrocution and collisions with wind turbines also exert an influence on the relative survival of different species.

The complex ecosystem of Dadia NP, along with its complex raptor assemblage, creates a highly dynamic system where raptors are influenced by competitive interactions and various environmental parameters at different ecological scales (Hakkarainen et al. 2004, Sánchez-Zapata and Calvo 2004). This region is highly sensitive, making it difficult to balance all components and maintain high population numbers for all species through management (i.e. one action that benefits one species might hinder another). Yet, by combining the Systematic Raptor Monitoring in combination with species-specific ecological studies, it is possible to identify key issues allowing the timely implementation of mitigation measures.

Conclusions

At present, five major conservation issues exist in the Dadia NP raptor assemblage:

The total number of occupied raptor territories in the NP appears to be stable over time, showing the viability of the ecosystem to host raptors; however, a parallel increase in common and generalist species has been observed and this may be causing a reduction in the number of territories occupied by the more specialist species with smaller populations.

The increase in homogenisation through forest encroachment on forest clearings that are no longer grazed and the change in the type of agricultural crops being planted through contract-farming, might be contributing to the decline in certain species, like the Lesser-spotted eagle, Long-legged buzzard and Honey buzzard.

Furthermore, the increase in certain forest dwelling species that favour the increase in the closed-canopy environment, such as the Northern goshawk, might also be placing more pressure on these declining species, including the Eurasian sparrowhawk and the Common kestrel, due to its greater competitive ability.

Except for raptor species with increasing and decreasing trends, some raptors exhibited relative stability, but with noticeable fluctuations, such as the Levant sparrowhawk, the Booted eagle and the Golden eagle. To determine whether the observed trends in these and all other raptor groups are indicative of normal population fluctuations or deviations from regularity, long-term monitoring is required to remove "noise." Therefore, without doubt, the SRM in Dadia NP must be continued without interruption to enrich the time-series data and to optimise management in the decades to come.

The important anthropogenic pressure which has been recently identified by other studies, denoting the impact of illegal poisoning and collisions with wind turbines is an additional limiting factor on raptor populations.

Acknowledgements

This paper is based on work conducted through WWF Greece projects for the conservation of the Dadia-Lefkimi-Soufli National Park and was partly supported by

the LIFE Nature project "Conservation of Birds of Prey in the Dadia Forest Reserve, Greece" (LIFE02NAT/GR/8497). We thank Stefan Schindler and Carlos Ruiz for coordinating and participating in the Systematic Raptor Monitoring scheme for many years, as well as Chiara Scandolara, Lise Pomarède, Elefterios Kakalis, Dimitris Bakaloudis, Chris Eastham, Hristo Hristov, Giorgos Catsadorakis and Javier Elorriaga for participating in the fieldwork. The work of EVS volunteers hosted by WWF Greece is also sincerely appreciated for their important support with data input. Special thanks are extended to Kostas Katselidis for support in developing R code for data analyses. We thank the reviewers Dr Stoyan Nikolov, Dr Yannis Matsinos and Dr Romain Julliard for providing constructive comments to improve the initial manuscript. Many thanks to Dr Vasileios Bontzorlos for providing constructive comments throughout the preparation of the manuscript and special thanks to Dr Gail Schofield for the review and linguistic editing of the text.

References

Adamakopoulos T, Gatzoyiannis S, Poirazidis K [Eds] (1995) Study on the assessment, the enhancement of the legal Infrastructure and the management of the Protected Area in the Forest of Dadia. Specific Environmental Study, Volumes A, B and C. ACNAT Project. Ministry of Environment, Physical Planning and Public Works, Ministry of Agriculture &WWF-Greece, Athens.

Aradis P, Andreotti A (2012) A preliminary overview of monitoring for raptors in Italy. Acrocephalus 33(154/155): 297–300.

Baldwin JD, Bosley JW, Oberhofer L, Bass OL, Mealey BK (2012) Long term changes, 1958–2010, in the reproduction of Bald eagles of Florida Bay, Southern Coastal Everglades. Journal of Raptor Research 46(4): 336–348. https://doi.org/10.3356/JRR-11-65.1

Bakaloudis DE, Vlachos CG, Holloway GJ (1998) Habitat use by Short-toed eagles Circaetus gallicus and their reptilian prey during the breeding season in Dadia. Journal of Applied Ecology 35: 821–828. https://doi.org/10.1111/j.1365-2664.1998.tb00001.x

Bakaloudis DE, Vlachos CG, Papageorgiou N, Holloway GJ (2001) Nest site habitat selected by Short-toed Eagles Circaetus gallicus in Dadia Forest (northeastern Greece). Ibis 143: 391–401. https://doi.org/10.1111/j.1474-919X.2001.tb04940.x

Barca B, Lindon A, Root-Bernstein M (2016) Environmentalism in the crosshairs: Perspectives on migratory bird hunting and poaching conflicts in Italy. Global Ecology and Conservation6: 189–207. https://doi.org/10.1016/j.gecco.2016.03.001

Bibby C, Burgess N, Hill D, Mustoe S (Eds) (2000) Bird census techniques, 2nd Edition, Academic Press, 302

Carrara E, Arroyo-Rodríguez V, Vega-Rivera JH, Schondube JE, de Freitas SM Fahrig L (2015) Impact of landscape composition and configuration on forest specialist and generalist bird species in the fragmented Lacandona rainforest, Mexico. Biological Conservation 184: 117–126. https://doi.org/10.1016/j.biocon.2015.01.014

Carrete M, Sánchez-Zapata JA, Martínez JE, Calvo JF (2002) Predicting the implications of conservation management: a territorial occupancy model of Bonelli's eagle in Murcia, Spain. Oryx 36(4): 349–356. https://doi.org/10.1017/S0030605302000698

Catsadorakis G (1994) Recent situation and changes of diurnal and nocturnal birds of prey in Prespa National Park (western Macedonia, Greece). Biologia Gallo-hellenica 22: 143-150

Catsadorakis G, Källander H (Eds) (2010) The Dadia–Lefkimi–Soufli Forest National Park, Greece: Biodiversity, Management and Conservation. WWF Greece, Athens, 103–114.

Colwel RK (2009) Chapter III.1 Biodiversity: Concepts, patterns and measurement. In: Levin SA, Carpenter SR, Godfray HCJ, Kinzig AP, Loreau M, Losos JB, Walker B, Wilcove DS, (Eds) The Princeton guide to Ecology, Princeton University Press, 257–263

Crick HQP, Baillie SR, Percival SM (1990) A review of raptor population monitoring in the UK. British Trust of Ornithology and Nature Conservancy Council.

Ferrer M, Negro JJ (2004) The near extinction of two large European predators: Super specialists pay a price. Conservation Biology 18(2): 344-349 https://doi.org/10.1111/j.1523-1739.2004.00096.x

Fewster RM, Buckland ST, Siriwardena GM, Baillie SR, Wilson JD (2000) Analysis of population trends for farmland birds using Generalized Additive Models. Ecology 81(7): 1970–1984. https://doi.org/10.2307/177286

Fuller MR, Moscher JA (1987) Raptor survey techniques, Chapter 4. In: Pendleton BG, Millsap BA, Cline KW, Bird DM (Eds) Raptor Management Techniques Manual. National Wildlife Federation: 37–65.

Futuyma DJ, Moreno G (1988) The evolution of ecological specialization. Annual Review of Ecology and Systematics 19(1): 207–233. https://doi.org/10.1146/annurev.es.19.110188.001231

Galushin V (2012) An overview of the most significant recent (1990-2012) raptor monitoring studies in European Russia. Acrocephalus 33(154/155): 315–319.

Gamauf A (2012) A preliminary overview of raptor monitoring in Austria. Acrocephalus 33(154/155): 159–166.

Gamauf A, Tebb G, Nemeth E (2013) Honey Buzzard Pernis apivorus nest site selection in relation to habitat and the distribution of Goshawks *Accipiter gentilis*. Ibis 155(2): 258–270. https://doi.org/10.1111/ibi.12023

Gil-Sánchez JM, Moleón M, Otero M, Bautista J (2004) A nine year study of successful breeding in a Bonelli's eagle population in southeast Spain: A basis for conservation. Biological Conservation, 118(5): 685–694. https://doi.org/10.1016/j.biocon.2003.10.017

Gilbert G, Gibbons DW, Evans J (2011) Bird monitoring methods: A manual of techniques for key UK species. Pelagic Publishing, 466 pp.

Guisan A, Edwards TC, Hastie T (2002) Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecological Modelling 157: 89–100. https://doi.org/10.1016/S0304-3800(02)00204-1

Hakkarainen H, Mykrä S, Kurki S, Tornberg R, Jungell S (2004) Competitive interactions among raptors in boreal forests. Oecologia 141(3): 420–424. https://doi.org/10.1007/s00442-004-1656-6

Hallmann B (1979) Guidelines for the conservation of birds of prey in Evros. A report to IUCN/WWF International. Project 1684 aimed at the conservation of birds of prey in NE Greece. WWF International, Gland.

Hastie T, Tibshirani R(1986) Generalized Additive Models. Statistical Science 1(3): 297–318. https://doi.org/10.1214/ss/1177013609

Hernández M, Margalida A (2009) Poison-related mortality effects in the endangered Egyptian vulture (Neophron percnopterus) population in Spain. European Journal of Wildlife Research 55(4): 415–423. https://doi.org/10.1007/s10344-009-0255-6

Iankov P (Ed.) (2007) Atlas of breeding birds in Bulgaria. Bulgarian Society for the Protection of Birds.

Jankowiak L, Antczak M, Kwieciński Z, Szymański P, Tobolka M, Tryjanowski P (2015) Diurnal raptor community wintering in an extensively used farmland. Ornis Fennica92: 76–86. http://www.ornisfennica.org/pdf/latest/152Jankowiak.pdf

Julliard R, Clavel J, Devictor V, Jiguet F, Couvet D (2006) Spatial segregation of specialists and generalists in bird communities. Ecology Letters 9(11): 1237–1244. https://doi.org/10.1111/j.1461-0248.2006.00977.x

Kafetzis A, Kret E, Skartsi D, Vasilakis D, Christopoulou I (2017) Wind Farms in areas of high ornithological value—conflicts, solutions, challenges: The case of Thrace, Greece. In: Koppel J (Ed.) Wind, Energy and Wildlife Interactions, Springer International Publishing AG 2017, 191–206. https://doi.org/10.1007/978-3-319-51272-3_11

Kati V, Devillers P, Dufrêne M, Legakis A, Vokou D, Lebrun P (2004a) Testing the value of six taxonomic groups as biodiversity indicators at a local scale. Conservation Biology 18(3): 667–675. https://doi.org/10.1111/j.1523-1739.2004.00465.x

Kati V, Dufrêne M, Legakis A, Grill A, Lebrun P (2004b) Conservation management for Orthoptera in the Dadia reserve, Greece. Biological Conservation 115(1): 33–44. https://doi.org/10.1016/S0006-3207(03)00091-0

Kati V, Foufopoulos J, Ioannidis Y, Papaioannou H, Poirazidis K, Lebrun P (2007) Diversity, ecological structure and conservation of herpetofauna in a Mediterranean area (Dadia National Park, Greece). Amphibia-Reptilia 28(4): 517–529. https://doi.org/10.1163/156853807782152471

Kati V, Sekercioglu CH (2006) Diversity, ecological structure, and conservation of the landbird community of Dadia reserve, Greece. Diversity and Distributions 12(5): 620–629. https://doi.org/10.1111/j.1366-9516.2006.00288.x

Katzner T, Milner-Gulland EJ, Bragin E (2007) Using modeling to improve monitoring of structured populations: Are we collecting the right data? Conservation Biology 21(1): 241–252. https://doi.org/10.1111/j.1523-1739.2006.00561.x

Kirk DA, Hyslop C (1998) Population status and recent trends in Canadian raptors: A review. Biological Conservation 83(1): 91–118. https://doi.org/10.1016/S0006-3207(97)00051-7

Kovács A, Mammen UCC, Wernham CV (2008) European monitoring for raptors and owls: state of the art and future needs. Ambio 37(6): 408–412. https://doi.org/10.1579/0044-7447(2008)37[408:EMFRAO]2.0.CO;2

Kret E, Saravia V, Dobrev V, Popgeorgiev, Nikolov S (2016) Assessment of major threats in Natura 2000 sites for the Egyptian Vulture (*Neophron percnopterus*) in Bulgaria and Greece

(2012-2015). Fact sheet under action A3 of the LIFE+ project "The Return of the Neophron" (LIFE10 NAT/BG/000152). WWF Greece, Athens, 8 pp.

Magurran AE (2003) Measuring biological diversity. Wiley-Blackwell, 256 pp.

McLeod A (2015) R Package "Kendall". http://www.stats.uwo.ca/faculty/aim

Millsap B, Lefranc MLJr (1988) Road transect counts for raptors: how reliable are they? Journal of Raptor Research 22(1): 8–16. https://doi.org/10.1080/00063659709461051

Nielsen JT, Moller AP (2006) Effects of food abundance, density and climate change on reproduction in the sparrowhawk Accipiter nisus. Oecologia 149(3): 505–518. https://doi.org/10.1007/s00442-006-0451-y

Ntemiri K, Saravia V (2016) The status of the illegal use of poison baits in Greece. 2012-2015. Technical report under action C1 of the LIFE+ project "The Return of the Neophron" (LIFE10 NAT/BG/000152) Hellenic Ornithological Society, Athens, 39 pp.

Oppel S, Dobrev V, Arkumarev V, Saravia V, Bounas A, Kret E, Velevski M, Stoychev S, Nikolov SC (2015) High juvenile mortality during migration in a declining population of a long-distance migratory raptor. Ibis 157(3): 545–557. https://doi.org/10.1111/ibi.12258

Oppel S, Dobrev V, Arkumarev V, Saravia V, Bounas A, Kret E, Skartsi T, Velevski M, Stoychev S, Nikolov S (2016) Assessing the effectiveness of intensive conservation actions: Does guarding and feeding increase productivity and survival of Egyptian Vultures in the Balkans? Biological Conservation 198: 157–164. https://doi.org/10.1016/j.biocon.2016.04.002

Oppel S, Dobrev V, Arkumarev V, Saravia V, Bounas A, Manolopoulos A, Kret E, Velevski M, Popgeorgiev GS, Stoyan CS (2017) Landscape factors affecting territory occupancy and breeding success of Egyptian Vultures on the Balkan Peninsula. Journal of Ornithology 158(2): 443–457. https://doi.org/10.1007/s10336-016-1410-y

Palma L (2012) A preliminary overview of monitoring for raptors Portugal. Acrocephalus 33(154/155): 309–313.

Petty SJ, Anderson DIK, Davison M, Little B, Sherratt TN, Thomas CJ, Lambin X (2003) The decline of Common Kestrels *Falco tinnunculus* in a forested area of northern England: The role of predation by Northern Goshawks *Accipiter gentilis*. Ibis 145(3): 472–483. https://doi.org/10.1046/j.1474-919X.2003.00191.x

Poirazidis K, Goutner V, Skartsi T, Stamou G (2004) Modelling nesting habitat as a conservation tool for the Eurasian black vulture (Aegypius monachus) in Dadia Nature Reserve, northeastern Greece. Biological Conservation 118(2): 235–248. https://doi.org/10.1016/j.biocon.2003.08.016

Poirazidis K, Goutner V, Tsachalidis E, Kati V (2007) Comparison of nest-site selection patterns of different sympatric raptor species as a tool for their conservation. Animal Biodiversity and Conservation 30(2): 131–145.

Poirazidis K, Kati V, Schindler S, Kalivas D, Triakonstantis D, Gatsogiannis ST (2010) Landscape and biodiversity in Dadia-Lefkimi-Soufli Forest National Park. In: Catsadorakis G, Källander H (Eds) The Dadia-Lefkimi-Soufli Forest National Park: Biodiversity, Management and Conservation. WWF Greece, Athens, 103–114.

Poirazidis K, Schindler S, Kakalis E, Ruiz C, Bakaloudis DE, Scandolara C, Eastham C, Hristov H, Catsadorakis G (2011) Population estimates for the diverse raptor assemblage of Dadia National Park, Greece. Ardeola 58(1): 3–17. https://doi.org/10.13157/arla.58.1.2011.3

Poirazidis K, Schindler S, Ruiz C, Scandolara C (2009) Monitoring breeding raptor populations - a proposed methodology using repeatable methods and GIS. Avocetta 69: 59–69.

Poirazidis K, Xofis P, Skartsi T, Kret E, Kafetzis A (2015) Recording, mapping and evaluation of land cover variation in the Dadia-Lefkimi-Soufli National Park, for the period 1975-2015. In: Bakaloudis D (Ed.) Biodiversity in the Dadia-Lefkimi-Soufli National Park: Lessons of conservation for Specially Protected Areas, 14-15 November 2015, Dadia Evros, 76-80.

R Core Team (2017) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Rooney E, Montgomery WI (2013) Diet diversity of the Common Buzzard (Buteo buteo) in a vole-less environment. Bird Study 60(2): 147–155. https://doi.org/10.1080/00063657.2013.772085

Rutz C (2006) Home range size, habitat use, activity patterns and hunting behaviour of urban breeding Northern Goshawks Accipiter gentilis. Ardea 94(2): 185–202. http://www.avibirds.com/pdf/H/Havik4.pdf

Sánchez-Zapata JA (2012) A preliminary overview of raptor monitoring in Spain. Acrocephalus 33(154/155): 321–323

Sánchez-Zapata JA, Calvo JF (1999) Raptor distribution in relation to landscape composition in semi-arid Mediterranean habitats. Journal of Applied Ecology 36(2): 254–262. https://doi.org/10.1046/j.1365-2664.1999.00396.x

Saravia V, Kret E, Dobrev V, Nikolov S (2016) Assessment of mortality causes for the Egyptian Vulture (Neophron percnopterus) in Bulgaria and Greece (1997–2015). Fact sheet under action A1 of the LIFE+ project "The Return of the Neophron" (LIFE10 NAT/BG/000152). HOS, Athens, 9 pp.

Saurola P (2008) Monitoring birds of prey in Finland: a summary of methods, trends, and statistical power. Ambio 37(6): 413–419. https://doi.org/10.1579/0044-7447(2008)37[416:MBOPIF]2.0.CO;2

Schindler S, Poirazidis K, Ruiz C, Elorriaga J, Scandolara C (2011) The systematic GIS-based monitoring of diurnal forest raptors in Dadia National Park, Greece. In: Zuberogoitia I, Martínez JE (Eds) Ecology and conservation of european forest dwelling raptors. Departamento de Agricultura de la Diputación Foral de Bizkaia, Bilbao, 115–125.

Schindler S, Poirazidis K, Ruiz C, Scandolara C, Cárcamo B, Eastham C, Catsadorakis, G (2015) At the crossroads from Asia to Europe: spring migration of raptors and black storks in Dadia National Park (Greece). Journal of Natural History 49(5-8): 285–300. https://doi.org/10.1080/00222933.2013.836760

Schindler S, Poirazidis K, Wrbka T (2008) Towards a core set of landscape metrics for biodiversity assessments: A case study from Dadia National Park, Greece. Ecological Indicators 8(5): 502–514. https://doi.org/10.1016/j.ecolind.2007.06.001

Siriwardena GM, Baillie SR, Buckland ST, Fewster RM, Marchant JH, Wilson JD (1998) Trends in the abundance of farmland birds: A quantitative comparison of smoothed Common Birds Census indices. Journal of Applied Ecology 35(1): 24–43. https://doi.org/10.1046/j.1365-2664.1998.00275.x

Skartsi T, Elorriaga JN, Vasilakis DP, Poirazidis K (2008) Population size, breeding rates and conservation status of Eurasian black vulture in the Dadia National Park, Thrace, NE

Greece. Journal of Natural History 42(5–8): 345–353. https://doi.org/10.1080/00222-930701835290

Skartsi T, Dobrev V, Oppel S, Kafetzis A, Kret E, Karampatsa R, Saravia V, Bounas T, Vavylis D, Sidiropoulos L, Arkumarev V, Dyulgerova S, Nikolov S (2014) Assessment of the illegal use of poison in Natura 2000 sites for the Egyptian Vulture in Greece and Bulgaria during the period 2003-2012. Technical report under action A3 of the LIFE+ project "The Return of the Neophron" (LIFE10 NAT/BG/000152). WWF Greece, Athens, 75 pp.

Spasov S, Arkumarev V, Dobrev D, Dobrev V (2012) An overview of monitoring for raptors in Bulgaria. Acrocephalus 33(154/155): 181–189.

Stjernberg T, Koivusaari J, Högmander J, Ollila T, Ekblom H (2006) Population trends and breeding success of the White-tailed Sea Eagle *Haliaeetus albicilla* in Finland, 1970–2005. In: Koskimies P, Lapshin NV (Eds) Status of raptor populations in eastern Fennoscandia. Karelian Research Centre of the Russian Academy of Sciences, Finnish-Russian Working Group on Nature Conservation, Petrozavodsk, 151–159.

Strandberg R, Klaassen RHG, Hake M, Alerstam T (2009) How hazardous is the Sahara Desert crossing for migratory birds? Indications from satellite tracking of raptors. Biology Letters 6(3): 297–300. https://doi.org/10.1098/rsbl.2009.0785

Suárez S, Balbontín J, Ferrer M (2000) Nesting habitat selection by booted eagles *Hieraaetus pennatus* and implications for management. Journal of Applied Ecology 37(2): 215–223. https://doi.org/10.1046/j.1365-2664.2000.00503.x

Terraube J, Arroyo B, Madders M, Mougeot F (2011) Diet specialization and foraging efficiency under fluctuating vole abundance: A comparison between generalist and specialist avian predators. Oikos 120(2): 234–244. https://doi.org/10.1111/j.1600-0706.2010.18554.x

Triantakonstantis DP, Kollias VJ, Kalivas DP (2006) Forest re-growth since 1945 in the Dadia forest nature reserve in northern Greece. New Forests 32(1): 51–69. https://doi.org/10.1007/s11056-005-3626-1

Urcun JP (2012) A preliminary overview of raptor monitoring in France. Acrocephalus, 33(154/155): 217–223.

Väli Ü, Tuvi J, Sein G (2017) Agricultural land use shapes habitat selection, foraging and reproductive success of the Lesser Spotted Eagle Clanga pomarina. Journal of Ornithology 158(3): 841–850. https://doi.org/10.1007/s10336-017-1443-x

Vasilakis DP, Poirazidis KS, Elorriaga JN (2008) Range use of a Eurasian black vulture (Aegypius monachus) population in the Dadia-Lefkimi-Soufli National Park and the adjacent areas, Thrace, NE Greece. Journal of Natural History 42(5–8): 355–373. https://doi.org/10.1080/00222930701835308

Vasilakis D, Whitfield D, Kati V (2017) A balanced solution to the cumulative threat of industrialized wind farm development on cinereous vultures (*Aegypius monachus*) in south-eastern Europe. PlosONE 12(2): e0172685. https://doi.org/10.1371/journal.pone.0172685

Velevski M, Nikolov SC, Hallmann B, Dobrev V, Sidiropoulos L, Saravia V, Tsiakiris R, Arkumarev V, Galanaki A, Kominos T, Stara K, Kret E, Grubac B, Lisicanec E, Kastritis T, Vavylis D, Topi M, Hoxha B, Oppel S (2015) Population decline and range contraction of the Egyptian Vulture Neophron percnopterus in the Balkan Peninsula. Bird Conservation International 25(4): 440–450. https://doi.org/10.1017/S0959270914000343

Vermeersch G, Paquet JY (2012) A preliminary overview of monitoring for raptors in Belgium. Acrocephalus 33(154/155): 238–284.

Vlachos CG, Papageorgiou NK (1996) Breeding biology and feeding of the Lesser Spotted Eagle *Aquila pomarina* in Dadia Forest, North-Eastern Greece. In: Meyburg BU, Chancellor RD (Eds) Eagle Studies, WWGBP, Berlin, 337–347.

Voříšek P, Klvaňová A, Wotton S, Gregory RD (Eds) (2008) A best practice guide for wild birds monitoring. CSO/RSPB, JAVA Trebon, Czech Republic, 151 pp.

Vos P, Meelis E, Ter Keurs WJ (2000) A framework for the design of ecological monitoring programs as a tool for environmental and nature management. Environmental Monitoring and Assessment 61: 317–344. https://doi.org/10.1023/A:1006139412372

Vrezec A, Duke G, Kovács A, Saurola P, Wernham C, Burfield I, Movalli P, Bertoncelj I (2012) Overview of raptor monitoring activities in Europe. Acrocephalus 33(154/155): 145–157. https://doi.org/10.2478/v10100-012-0003-y

Wichmann MC, Jeltsch F, Richard W, Dean J, Moloney KA, Wissel C (2003) Implication of climate change for the persistence of raptors in arid savanna. Oikos102(1): 186–202. https://doi.org/10.1034/j.1600-0706.2003.12044.x

Witmer GW (2005) Wildlife population monitoring: Some practical considerations. Wildlife Research 32(3): 259–263. https://doi.org/10.1071/WR04003

Wood SN (2012) R Package "mgcv". http:\\cran.r-project.org\web\packages\mgcv\mgcv.pdf

Zakkak S, Kakalis E, Radović A, Halley JM, Kati V (2014) The impact of forest encroachment after agricultural land abandonment on passerine bird communities: The case of Greece. Journal for Nature Conservation 22(2): 157–165. https://doi.org/10.1016/j.jnc.2013.11.001

Zografou K, Adamidis G, Grill A, Kati V, Wilson R, Halley J (2015) Who flies first? Habitat-specific phenological shifts of butterflies and orthopterans in the light of climate change: a case study from the south-east Mediterranean. Ecological Entomology 40: 562–574. https://doi.org/10.1111/een.12220

Supplementary material 1

Map of Dadia-Lefkimi-Soufli National Park, vantage points and line transects

Authors: Konstantinos Poirazidis

Data type: PNG image file

Explanation note: Map of Dadia-Lefkimi-Soufli National Park, indicating the 24 different monitoring vantage points and 10 different line transects, along with the borders of the Special Protected Area core within the National Park.

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/natureconservation.22.20074.suppl1